A STUDY OF THE EFFECT OF THE DIGESTIBILITY OF HAY ON ITS FEEDING VALUE, WHEN GIVEN TO LACTATING COWS GRAZING ON PASTURE

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ABSTRACT.

Sixteen cows with an average milk yield of 20 litres per day, were randomly allocated to two treatment groups. One group was supplemented with high digestibility hay (57.3% DMD) while the other group was supplemented with low digestibility hay (52.0% DMD). Cows in both treatments grazed on pasture during the night time and were stall-fed with either high or low digestibility hay during the day time. The pastures were predominantly of perennial ryegrass (*Lolium perene*). The experiment was carried out for 28 days in September 1988.

The two treatment groups were given a common pasture allowance of 11-12 kgDM per cow per 12 hour period of grazing. Hay intake (fed *ad libitum*), pasture intake, milk yield, milk composition, liveweight and condition score were measured.

Herbage intake was estimated by the sward cutting technique and was 3.85 and 4.30 kgDM per cow per day for the high and low digestibility hay groups respectively. The difference between the groups in intake was significant ($P<0.05$). Daily intake of high digestibility hay (8.65 kgDM per cow) was significantly ($P<0.0001$) greater than the consumption of low digestibility hay (6.53 kgDM per cow). The estimated values for daily metabolisable energy intake were 115 MJ per cow and 99 MJ per cow for the high digestibility and low digestibility hay groups respectively. Residual herbage mass was slightly higher (1130 v 1100 kgDM per hectare), but not significantly, when cows were supplemented by high digestibility hay. Substitution rate for the increase in hay intake was -0.45 kgDM pasture intake for an increase of 2.12 kgDM of hay intake or 0.21 kgDM pasture per one kgDM increase in hay intake.

Cows fed on the high digestibility hay produced slightly more milk than those on the low digestibility hay. The difference was significant ($P<0.01$) in week 1 but not significant thereafter. Yields of milk constituents were also slightly increased for cows fed on the high digestibility hay.

Digestibility of hay had small and insignificant effects on the concentrations of milk fat, milk protein and milk lactose. However the concentration of milk fat and milk protein were slightly higher for cows fed low digestibility hay. Cows fed high digestibility hay gained significantly more liveweight ($P<0.05$) and condition score ($P<0.01$) than cows fed low digestibility hay.

The total intake in cows fed on high digestibility hay was significantly ($P<0.001$) higher than in cows fed on low digestibility hay. It was estimated that hay intake increased by 0.40 kgDM per unit rise in hay digestibility and milk production increased by 0.23 kg milk per unit rise in hay digestibility. The increase in hay intake and milk production per unit rise in digestibility is normally similar to other studies with which the range response of -0.12 to 0.72 kgDM increase in intake per unit rise in digestibility and 0.00 to 0.93 kg milk increase in milk yield per unit rise in digestibility. However the present study was the only experiment for dairy cows grazing on pasture.

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CHAPTER 1

INTRODUCTION

Dairy cow feeding in New Zealand has traditionally relied heavily on low cost grazing of high quality pasture. However, seasonal variations of the pattern of pasture growth is likely to cause pasture deficits at some times and surpluses in others. Plans of nutrition management are, therefore, used as an attempt to match animal feed demand to pasture feed supply. In general, herd are seasonally milked, calving during late winter so that peak requirements of feed in early lactation can coincide with rapid pasture growth in the spring. Pasture which is surplus to the requirements of the herd is conserved as hay and/or silage and is usually fed back during the period of pasture deficits i.e. late summer and winter.

During winter, supplementary feed, particularly hay and silage is commonly given to lactating cows which are grazing on limited supplies of pasture on "market milk" farms where milk is produced in winter for local consumption. The digestibility of a feed is known to be an important feature of its feeding value. Hay normally used on dairy farm can vary in its digestibility between 50% - 65% with ME concentrations of 6.7 - 9.0 MJ per kgDM (Rogers, 1985).

However, there has been no experimental work in New Zealand to study the effect of the digestibility of a supplementary feed on its feeding value for lactating cows. The present study was, therefore, designed and initiated to investigate the effect of digestibility of a supplementary feed on its feeding value when given to lactating cows grazing on restricted pasture.

Several experiments (Rogers, 1985, Stockdale and King 1982) have shown the poor responses when hay is fed as a supplement to a restricted pasture in early lactation, each kg hay gave 9 gm. extra milk fat directly and 23 gm. extra milk fat over the whole lactation, whereas each kg pasture gave 42 and 80 gm. extra milk fat respectively. However, Rogers (1985) suggested that in dry climates where hay can be made earlier in spring from high quality pasture, milk responses are likely to be improved. Thus, it is possible that both long term and short term responses of supplementary feeding can be improved by conserving the pasture with minimum losses in quality at a reasonable cost.

The present study attempts to detail and report the responses of lactating cows to supplementary feeding of hays which differ in digestibility. This includes the immediate and long term responses in milk yield and milk composition, together with liveweight and condition score changes.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Factors affecting milk production from grazed pasture and the need for supplementary feed.

New Zealand dairy farmers must rely heavily on grazed pasture as the main source of feed for all stock because of the relatively low price received from the sale of milk. Effective feeding of the herd must ensure that the herd feed's requirements are matched as closely as possible to the supply of pasture throughout the year, within the constraints of farm economics (Holmes and Wilson, 1984; Bryant and Sheath, 1987).

Farm profit is affected more strongly by milk yield per hectare rather than milk yield per cow. Milk yield per hectare is affected by grass grown per hectare, grass eaten per hectare and feed conversion efficiency. Stocking rate is seen to be the key factor affecting milk per hectare. In addition, stocking rate is also the most important factor which affects the herd's feed requirement per hectare (Holmes and MacMillan, 1982; Holmes and Wilson 1984; Holmes, 1987; Bryant and Sheath, 1987) and is also the vital factor in all grazing management (Castle and Watkin, 1984). At a low stocking rate, the herd's feed requirements can be satisfied by pasture feed supply in each individual month of the year. However there may be a large surplus of pasture in several months, particularly in the spring (Figure 2.1a). Much of the surplus pasture would probably be wasted through the process of death and decay (Holmes and Wilson, 1984). Undergrazing at low stocking rate can also depress pasture growth and pasture quality (Campbell, 1964; Campbell, 1969). Therefore, low stocking rates are generally associated with lower milk yield per hectare and low farm profitability.

At a high stocking rate, the total annual yield of herbage may be equal to the total annual feed requirements of the stock but a feed deficit may occur in late winter / early spring and late summer, with surplus in spring and autumn (Figure 2.1b). The deficit which occurs in early spring can be eliminated by delaying calving date but this may shorten the lactation (Figure 2.1c). A higher stocking rate , in contrast with lower stocking rate, is generally associated with higher milk yield per hectare and higher farm profitability.

With market milk supply, farms generally produce a year round supply of fresh liquid milk. To achieve this, some cows will calve at times other than in spring time. There is, therefore, less variation of herd's feed requirements between months than that seen on the seasonal supply farms (Figure 2.1d). Thus, the winter feed deficit is larger than that on the seasonal supply farms at the same level of stocking rate because lactating cows require more feed than non-lactating cows (Holmes and Wilson 1984).

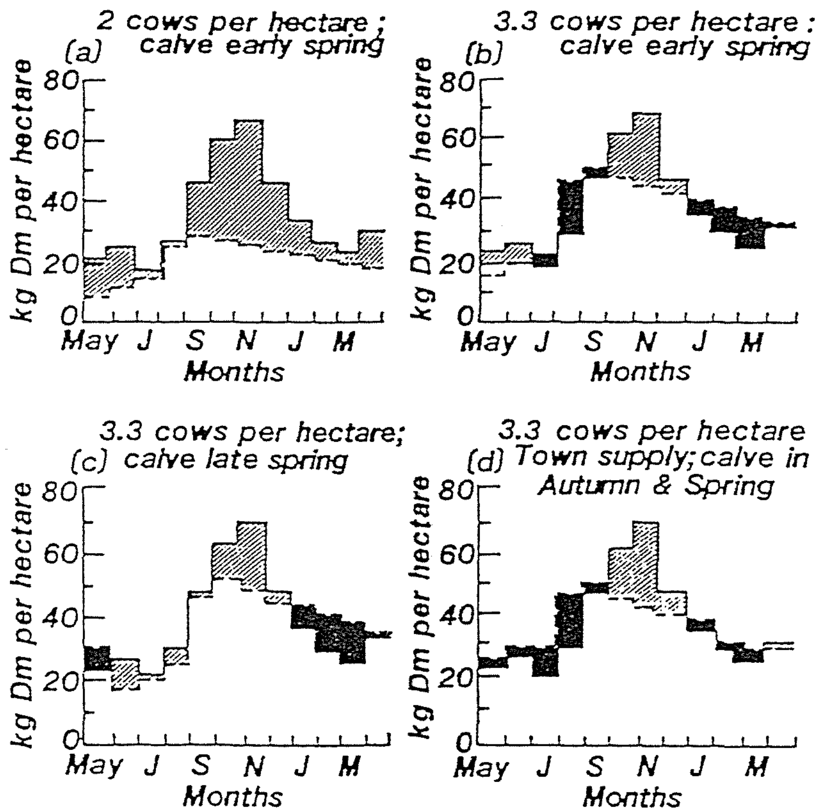


Figure 2.1 The quantities for herbage grown (____) and eaten (_ _ _ _) in each month of the year; surpluses (hatched) and deficits (black) of herbage are shown for two stocking rates and different calving date.

Achievement of high yield of milk per hectare of pasture requires an appropriate, relatively high stocking rate, to minimise wastage over the year i.e. total feed grown equal to total feed eaten. But in some months the amount grown is much less than the amount which must be eaten, for instance in late winter/early spring or in dry summer or in market milk farm (Holmes,1987). The management of pasture , including accumulation, transferring and rationing for deficit periods and compromising between unrestricted feeding and the maintenance of pasture quality during period of surpluses are likely to be the strategies used to match the animal's feed demand to the supply of feed throughout the year (Sheath *et al.* 1987).

Supplements are required and normally offered to grazing dairy cows to relieve shortfall in herbage intake. The market milk farmers generally make and feed significantly more hay and silage and total supplements than seasonal supply farmers (Brookes and Holmes, 1988; Baldwin, 1989).

<u>**Effects of supplementary feeding.**</u>

A supplementary feed (hay, silage, concentrate) given to cows grazing on pasture has a number of main effects.

- A direct energy boosting effect, since hay fed to cows grazing on restricted pasture will generally increase total DM intake (Rearte *et al.* 1986). This will obviously have a direct effect on the cow's condition at the end of winter (Rogers, 1985; Franco, 1988) with reduced body condition loss or an increase in milk yield in early lactation (Grainger, 1979).

- A pasture sparing effect, when hay is supplemented, as pasture intake will be reduced and pasture will be grazed less intensely. This is likely to have a direct effect on the accumulation of pasture at the end of the period of supplementation (Rogers, 1985; Bryant and Sheath, 1987; Franco, 1988).

- Finally, the pasture sparing effect may cause an increase in rate of regrowing during winter since, in cool weather, pasture growth rate is influenced by pasture mass (Santamaria and McGowan, 1982). This is due to a reduction in intensity of grazing and the increase in photosynthetic tissue remaining after grazing (Butterworth, 1985). This will increase quantity of pasture present on the farm at the end of winter (Franco, 1988) with a small decline in pasture quality (Santamaria and McGowan, 1982).

2.2 Effects of feeding level in early lactation.

It was agreed in many experiments that the level of feeding for the cows in early lactation has a profound effect upon milk production at that time and in some cases can affect yield for the rest of the lactation (Holmes and Wilson, 1984). Underfeeding of the cow after calving will result in a decrease in milk production and an increase in body weight loss, at least at the period of underfeeding and with the likelihood of carry over effect for the rest of lactation (Broster, 1971; Broster, 1972; Grainger, 1982; Broster and Broster, 1984; Broster *et al.* 1984; Holmes and Wilson, 1984; Stockdale *et al.* 1987). Bryant and Trigg (1982) reviewed several experiments in Australia and New Zealand and concluded that an average restriction of 38% in DM intake resulted in a reduction of 24% in milk fat yield, generally reduced protein and SNF concentration in milk.

The time (Grainger and Wilhelm, 1979) and duration of underfeeding (Broster and Broster, 1984) can affect the animal performance. Generous feeding after calving will not entirely compensate for poor feeding before calving (Bryant, 1980), if the cow calves in low body condition score (Grainger *et al.* 1982) despite a positive interaction between body condition at calving and feeding level in week 1-5 for milk and milk fat yield (20 weeks) observed by Grainger *et al.* (1982).

Increasing the feeding level of lactating cows will normally result in an increase in milk production (Holmes and Wilson, 1984). Production responses to changes in feeding level are often divided into immediate response and carry-over effects. An immediate response is defined as the change in milk production which occurs during the actual period of the treatment (Wilson and Davey, 1982), whereas the carry over effect is measured after the period of differential feeding has finished.

2.2.1 Effects of level of feeding in early lactation on milk yield and milk composition.

2.2.1.1 Immediate effects.

A large number of feeding experiments conducted in New Zealand and Australia have shown that underfeeding in early lactation reduces milk yield and alters the composition of milk (Bryant and Trigg, 1982). The mean response to an extra one kgDM pasture is an extra 39 gm. milk fat and 174 gm. of extra liveweight (Bryant and Trigg, 1982). These quantities represent approximately 5.0 and 5.9 MJME intake respectively (Holmes and Wilson, 1984) and the total of 10.9 MJME extra is a good agreement with a likely ME content of one kgDM from spring pasture (Bryant and Trigg, 1982). It should be emphasised, however that this value represents a mean response and that there is great variability in the actual responses reported (Bryant and Trigg, 1982). This variability may be attributed to differences in the extent of partitioning of feed energy between milk production and body weight gain (Grainger and Wilhelm, 1979). The extent of the response to change in level of feeding in milk yield depends largely on the duration and severity of underfeeding (Grainger and Wilhelm, 1979; Bryant and Trigg, 1982; Wilson and Davey, 1982). In addition, the response is greater in high yielding than in lower yielding cows and is lower in mid-late lactation than in early lactation (Broster *et al.* 1981; Holmes and McMillan, 1982; Holmes and Wilson, 1984; Broster and Broster, 1984).

<u>Immediate effects on milk composition.</u>

Immediate effects of feeding level on milk composition are small and variable. A highly variable effect on fat concentration is evident but the effect on protein and SNF concentration is more consistent (Bryant and Trigg, 1982). Inconsistent responses in milk fat concentration may be due to the confounding effect of differing degree of mobilisation of body fat (Holmes and Wilson, 1984). In general, increasing the level of feeding in early lactation causes an increase in milk protein and SNF concentration (Holmes and Wilson, 1984) but the effects of feeding level on milk fat concentration are unpredictable (Bryant and Trigg, 1982). Grainger and Wilhelm (1979) suggested that milk fat percentage was significantly increased by underfeeding in the first five week of lactation. Milk fat concentration normally increases for a few weeks of underfeeding, but then decreases if underfeeding persists for long period due to the exhaustion of body reserves. Therefore, the effects of underfeeding on milk fat concentration as well as milk production are likely to increase as the duration of underfeeding increases (Bryant and Trigg, 1982).

2.2.1.2 Carry over effects (measure after the period of differential feeding).

Extra liveweight that results from extra feed in early lactation may subsequently be mobilised to produce milk (Holmes and McMillan, 1982; Holmes and Wilson, 1984). Similarly, loss of liveweight during underfeeding will be regained after the underfeeding; this will cause diversion of nutrients to body tissue away from milk. This, then, represents a carry over or residual effect on milk fat production subsequent to the period when the extra feed was given. The effects of underfeeding in early lactation on subsequent milk yield and composition have been intensively reviewed by Broster (1982); Bryant and Trigg (1982); Broster and Broster (1984).

The residual effect of feeding level in early lactation was reported by a large number of feeding experiments in New Zealand and Australia (Stockdale *et al.* 1981; Bryant and Trigg, 1982; Wilson and Davey, 1982; Rogers, 1985). The average residual effect is about 0.5 times of the immediate effect of underfeeding in early lactation with the range of -0.2 to 4.0 (Stockdale *et al.* 1981; Bryant and Trigg, 1982; Rogers, 1985). The value of 0.5 to 0.7 times of the immediate effect was reported by Wood and Newcomb (1976); Johnson (1977); Le Du *et al.* (1979). However, some experiments in New Zealand (Hutton and Parker, 1973; Bryant and Trigg, 1974; Glassey *et al.* 1980) and in the UK, (Cambellas and Hodgson 1979; Blair *et al.* 1981; Baker *et al.* 1982) have found no significant residual effect on yields caused by underfeeding in early lactation. These differences may be due to the variation between experiments in the duration and severity of underfeeding, stage of lactation, genetic merit, cow condition, subsequent level and quality of feeding (Holmes and Wilson, 1984) or the ability of the animal to recover from underfeeding (Bryant and Trigg, 1982).

The subsequent effects on milk composition are not clear. Flux and Patchell (1957) reported a residual fall in milk fat concentration following underfeeding in early lactation, whereas Grainger and Wilhelm (1979) did not observe this effect. Broster (1972) summarised early evidence showing residual effect on protein and SNF concentration in milk. However, more recent works (Steen and Gordon, 1980ab; Glassey *et al.* 1980) indicated no residual effect on milk composition. Bryant and

Trigg (1982) concluded that milk constituents can rapidly return to normal levels after underfeeding has finished.

2.2.2 Effects of level of feeding in early lactation on liveweight and/or condition score.

Body condition score is related to the fat concentration of the animal's body (Gray *et al.* 1981) and may provide a better estimate of the body energy reserves than would be provided by measurement of liveweight (Holmes *et al.* 1981; Holmes and Wilson, 1984).

<u>Effects of body condition at calving on milk production.</u>

The absolute liveweight or body condition at calving, and not the rate of change of liveweight or body condition, is the important factor affecting future milk yield (Rogers *et al.* 1979; Grainger *et al.* 1982; King *et al.* 1985). Neither the type of diet nor the pattern of feeding before calving had a significant effect on subsequent liveweight, milk yield or composition if the cows calved at similar condition scores (Hutton, 1962; Rogers *et al.* 1981). The body reserves achieved before calving become available for milk production in early lactation. The cows calving at fatter condition are, therefore, expected to produce more milk fat. Many experiments have shown that body condition or liveweight of cows at calving is the important factor affecting subsequent milk production rather than the rate of change (Hutton, 1972; Hutton and Parker, 1973; Grainger *et al.* 1982); Rogers *et al.* (1979). However, Grainger *et al.* (1982) and Holmes and Wilson (1984) suggested that liveweight gain before calving unaccompanied by better condition at calving, has little effect on production.

<u>Effects of body condition at calving on milk composition.</u>

Milk fat concentration of the cows of higher condition is higher compared with lower condition score (Grainger *et al.* 1982), since the mobilisation of body reserves in early lactation usually increases the fat concentration of milk produce at that time (Rogers *et al.* 1979; Holmes and Wilson, 1984). The condition score at calving, therefore, seems to have a greater effect on yield of milk fat than on yield of milk or protein (Grainger *et al.* 1982). However, this response is affected by the level of feeding in early lactation, cows at low level of feeding mobilise more body condition and this has a larger effect on milk fat concentration than for cows with higher feed intakes (Holmes and Wilson, 1984). Increase in body condition at calving also causes small increases in protein and SNF concentration in milk (Grainger *et al.* 1982; Grainger and McGowan, 1982).

2.2.2.1 Immediate effects.

Underfeeding in early lactation generally reduces body weight and condition score (Bryant and Trigg, 1979; Grainger *et al.* 1982; Grainger and McGowan, 1982). An extra one kgDM eaten caused an average response of 174 gm. extra liveweight, with a range of 27 - 540 gm.in Australian and New Zealand trials (Bryant and Trigg, 1982). The variability of response may be attributed to differences in the extent of partitioning of feed between milk and body gain (Holmes and Davey, 1981; Holmes and Wilson, 1984). For instance, cows calving at high condition score increase milk production by causing a more favourable partitioning of energy into milk production at the expense of liveweight (Grainger *et al.* 1982) but cows in lower condition score partition a high proportion of feed energy to liveweight gain at the expense of milk production (Grainger and McGowan, 1982). Also at a given body condition and level of intake postpartum, high producing cows partition a higher proportion of dietary nutrients to milk synthesis than low producing cows (Broster *et al.* 1975).

2.2.3.2 Carry over effects.

Cows fed less generously in early lactation subsequently gain more weight in mid lactation than did the previously better fed cows (Bryant and Trigg, 1979; Grainger and Wilhelm, 1979; Stockdale *et al.* 1981) and this occurred with generous or restricted grazing in mid lactation. The possible explanation is that poor condition cows, because of underfeeding in early lactation, favour partitioning of energy to liveweight gain at the expense of milk production (Grainger and McGowan, 1982). Grainger *et al.* (1982) reported that increasing the level of feeding during early lactation would conserve body tissues but better body condition at calving is associated with greater body loss at this period. In their review, Broster and Thomas (1981) summarised from 46 trials and concluded that the previously less generously fed cows gained 0.15 kg per day more weight in mid lactation than those well fed throughout.

2.3 Effects of supplementary feeding on grazing lactating cows.

The use of supplementary feed for grazing animals has been normally aimed to avoid underfeeding during the shortage of pasture (Holmes and Wilson 1984; Baldwin, 1989), to increase animal performance (Stockdale *et al.* 1981 ; Suksombat, 1989) and to save and transfer it to reduce a later gap between pasture production and animal requirements (Trigg *et al.* 1985; Sheath *et al.* 1987). Moreover when supplementary feed are purchased, farmers may more confidently choose a high stocking rate without jeopardizing on animal performance (Franco, 1988; Thomson, 1989).

2.3.1 Effects of supplementation on feed intake and substitution.

Supplementation generally causes a decrease in herbage DM intake when the supplement is fed with generous allowance of good quality pasture. However, the total DM intake is normally increased, (Hutton and Parker, 1966; Gordon, 1975; Eldridge and Kat, 1980a; Stockdale and King, 1983; Bryant and Trigg, 1982; Kaiser *et al.* 1987; Rogers and Robinson, 1985; Grainger, 1987; Franco, 1988; Suksombat, 1989). The increase in total DM intake is smaller than the amount of supplementary DM eaten, because of partial substitution between supplement and pasture (Eldridge and Kat, 1980a; Grainger and Mathews, 1989). Rogers (1985) defined the term substitution rate as the amount by which pasture DM intake is reduced when one kgDM of supplement is consumed. Several factors influence the response of the animal to the supplementation. These factors include type, quality and quantity of supplements, the overall feeding level and quality of herbage, physiological state of the animal as well as animal's condition score. All these factors interact with each other and not only affect the immediate response but also subsequent production (Rogers, 1985). However, the degree of subsequent production is largely affected by subsequent pasture growth. It is, therefore, difficult to predict the outcome of supplementary feeding with any precision (Bryant and Trigg, 1982; Rogers, 1985).

2.3.1.1 Type of supplements i.e. hay, silage and concentrate.

Supplementary feeds are generally offered to grazing dairy cows to alleviate shortfall in herbage availability, in order to increase total DM intake. The effects of type of supplements on substitution rate are variable (Umoh and Holmes, 1974; Vadiveloo and Holmes, 1979; Bryant and Trigg, 1982). This is probably due to the confounding effects of level of feeding, pasture quality or the balance of the whole diet. However, some evidence showed that supplementation with particular nutrients can increase the intake of pasture when diet is deficient in that particular nutrient. For instance, protein supplementation can increase pasture intake when the diet is deficient in protein (Mercer, 1976; Kempton, 1983; Steg *et al.* 1985; Moran *et al.* 1986). The protein supplementation, in this case, may maximise the bacterial growth in the rumen (ARC, 1980, Barry, 1982). It is recognised, in general, that the substitution rate at various physiological states for various feed was ranged between 0.02 to 0.95 (Tayler and Wilkinson, 1972; Marsh and Chestnutt, 1977; Meijs, 1981).

Total DM intake was usually increased with hay (Phillips and leaver, 1985a; Franco, 1988), silage (Phillips and Leaver, 1985b) or concentrate (Suksombat, 1989)supplementation to grazing cows but herbage intake was always reduced (Meijs, 1981; Tayler and Wilkinson, 1972).

Few experiments have compared hay as a supplement with other supplements. The DM substitution rate reported by Phillips and Leaver (1985a); Stockdale *et al.* (1981) Eldridge and Kat (1980a) for hay supplementation in lactating cows for the whole lactation was within the same range described for DM substitution rate for other feeds (Meijs, 1981; Tayler and Wilkinson, 1972; Marsh and Chestnutt, 1977; Leaver, 1986).

2.3.1.2 Level of feeding.

When cows graze on generous allowances of good quality pasture the animal response measured as extra milk yield and liveweight to any type of supplement is small, and substitution rate of pasture by the supplement is high (Meijs, 1981; Bryant and Trigg, 1982; Meijs and Hoekstra, 1984; Grainger and Mathews, 1989). It is evident that the differences between responses when supplements are fed at different pasture allowance are largely caused by different pasture substitution rates. Grainger and Mathews (1989) and Meijs and Hoekstra (1984) showed that the substitution rate decreased from 0.50 at high herbage allowance to 0.11 at low herbage allowance when concentrates were supplemented. Similar results were observed with hay supplementation as the decrease in herbage intake were 0.28 and 0.40 kg herbage DM per kg hay DM eaten at the lower and higher herbage allowances respectively (Franco, 1988).

2.3.1.3 Feed Quality.

The quality of supplement can directly affect the substitution rate. Meijs (1986) reported that, at high pasture allowance, the mean substitution rate was reduced from 0.45 with the supplementation of high starch concentrate (350 gm starch per kgDM) to 0.21 with the supplementation of low starch concentrate (100 gm starch/KgDM). A possibly explanation for the differences in substitution rate between types of supplements is given by Steg *et al.* (1985). The rate of rumen fermentation varies between different sources of carbohydrates (Johnson, 1977), with higher rates found when soluble sugars are fed (ARC, 1980) and the lowest rates when supplements rich in cell wall constituents are fed. High levels of easily fermented substances, such as soluble sugars, starch, some protein, etc., in the ration tend to decrease rumen pH and increase concentration of VFA and lactate in rumen fluid, resulting in a lower cellulolytic activity of the microbes in the rumen and lowers the rate of break down of fibrous particles in the recticulorumen (Steg *et al.* 1985; Meijs, 1986). As a result, the increased degree of rumen-fill with non-fermented residue may restrict intake of new feed (Meijs, 1986). A similar reduction in pasture DM intake when high starch concentrate was supplemented has been reported by Jennings and Holmes (1984). There is little information about the effect of quality of conserved forage supplementation. However, many experiments have been reported the positive relationship between silage intake and its digestibility (Castle and Watson, 1969, 1970, 1971; Gordon and Murdock, 1978; Castle *et al.* 1980; Gordon, 1980ab; Moisey and Leaver, 1984; Rogers and Robinson, 1984; Phipps *et al.* 1987). Thomas (1980) concluded from 15 experiments that silage intake in stall-fed dairy cows would increase by average 0.15 kgDM per unit rise in digestibility. King and Stockdale (1981) and Stockdale *et al.* (1981) stated that the quality of hay compared to pasture will determine the ability of supplements to alleviate the effect of underfeeding, but the comparison of supplements in different digestibility was not done. When hay in different digestibility was supplemented, Llamas-Lamas *et al.* (1987) observed that DM intake was higher for high digestibility hay (36.1 % NDF) than for low digestibility hay (51.7 % NDF). This difference was due to the high digestibility hay has a higher concentration of soluble DM with a faster rate of digestion. These factors contribute for the faster passage of the high digestibility hay and may result in higher intake (Llamas-lamas *et al.* 1987).

2.3.1.4 Physiological state.

Information about the effect of stage of lactation on DM substitution rate is contradictory. Phillips and Leaver (1985ab) reported an increase in substitution rate with the progress of lactation when conserved pasture was supplemented. However, Jennings and Holmes (1984) observed the opposite result where concentrate was supplemented.

2.3.2 Pasture sparing effects.

An increase in residual herbage mass is an inevitable consequence of a decrease in herbage intake. Supplementary feeding generally reduces the intensity of grazing (Santamaria and McGowan, 1982, Bryant, 1981, Bryant, 1982, Mathews and Gray, 1979). In their review, Bryant and Trigg (1982) summarised that for each one kgDM of supplement consumed, residual herbage mass is increased by 100-200 kgDM per hectare depending upon the stocking rate and the decrease in herbage intake per cow. The reason is that when cows are supplemented, herbage DM intake declines because of substitution, this causes an increase in residual herbage mass (Rogers, 1985, Franco, 1988, Suksombat, 1989).

The reduction in the severity of the defoliation and the increase in residual herbage mass when cows are supplemented, may increase subsequent pasture growth rates (Stockdale *et al.* 1984, Mathews and Gray, 1979, Hoogendoorn, 1987). Santamaria and McGowan, (1982) reported that pasture growth rate can increase by 20 kgDM per hectare per day for each increase of 1000 kgDM per hectare in residual pasture, when residual pasture is less than 2200 kgDM per hectare (Mathews and Gray, 1979). Pasture spared during supplementation may be carried forward to provide additional feed in the later period or it may be wasted through decay (Rogers, 1985). Alternatively, the increased in pasture growth in early spring may adversely affect pasture quality later in spring (Rogers, 1985).

2.3.3 Effects of supplementary feeding on milk yield and composition.

The effect of supplementary feeding on milk yield and milk composition was intensively reviewed by Bryant and Trigg (1982) and Rogers (1985). In a review of a large number of experiments, the average response was an extra 0.5 litre of milk or 21 gm. of milk fat for each additional one kgDM of supplement consumed , with the range of -0.2 to 1.4 litres or -6 to 63 gm. of milk and milk fat respectively (Bryant and Trigg,1982). Rogers (1985) concluded that the mean responses per kg supplement were 0.5 litres of milk and 17 gm. milk fat, while Journet and Dermarquilly (1979) concluded an average 0.4 litres of milk per kg supplement consumed. The variation in such responses are likely to be caused by the differences in type of supplements, in ME concentration per kgDM of supplement, in the quantity and quality of both pasture and supplement consumed, in stage of lactation, in cow quality and probably the combination of these factors affecting the response.

2.3.3.1 Type of supplements (eg. silage, hay or concentrate) .

<u>The effects of type of supplements on the yield of milk and its constituents.</u>

Most experiments have shown that , with restricted pasture, when supplement are fed, regardless of type of diet , yield of milk and its constituents generally increase. Based on limited information, Bryant and Trigg (1982) concluded in their review that there is no convincing evidence to indicate that the type of supplements has an effect on production response. Those factors including quality and quantity of supplement, frequency of feeding, and interaction among the factors in association with pasture factors may affect animal production response (Bryant and Trigg, 1982). Walsh (1969) also suggested that the difference in animal production responses per kg supplement observed when concentrate or hay were supplemented to grazing dairy cows, were probably due to the differences in their digestibility which causes differences in the ME intake of the cows. There were no consistent differences in production response between protein and energy supplemented when cows grazed on pasture (Rogers *et al.* 1981). Significantly greater responses to protein rather than energy supplement were observed in only 4 from 8 experiments and the best response was in early lactation (Kemptton, 1983). The reasons for the variation in responses are not completely understood (Rogers *et al.* 1981). In addition, the increase in milk yield with increasing ME concentration of the diet at a common ME intake was associated with an increasing proportion of proprionate in the rumen VFA (Sutton *et al.* 1980, Sutton *et al.* 1988).

<u>**Effects of type of supplements on the concentration of milk constituents.**</u>

While the production response is unlikely to be affected by type of supplement, at the common level of ME intake, the concentration of milk constituents was affected. It is agreed in general that milk fat concentration was depressed by concentrate supplementation but it was increased by silge supplementation (Jennings and Holmes, 1984, Stockdale and Trigg, 1985, Phillips and Leaver, 1985b, Arrija-Jordan and Holmes, 1986, Stakelum, 1986) or hay supplementation (Sheath *et al.* 1957, Castle *et al.* 1960, Walsh, 1969). However Stockdale *et al.* (1981) and Phillips and Leaver (1986a) suggested that fat concentration was unlikely to be affected significantly by hay supplementation, although it may be increased slightly. The reduction in milk fat concentration with concentrates has been suggested to be due to a high production of proprionic acid and low production of acetic and butyric acids in the rumen, depressing the synthesis of milk fat and increasing the synthesis of body tissue (Rook and Thomas, 1983; Broster *et al.* 1985; Sutton *et al.* 1988). Hay supplementation has no effect on milk protein concentration, but silage generally reduces protein concentration slightly, probably because of relative underfeeding (Phillips and Leaver, 1985b). Milk lactose concentration is unlikely to be affected by the type of supplements because of the volume of milk produced controlled by the amount of lactose synthesized in the mammary gland (Rook and Thomas, 1983; Holmes and Wilson, 1984; Sutton *et al.* 1988).

2.3.3.2 Level of feeding.

It is generally accepted that the animal production response to supplementary feeding (kg per kgDM supplement) is decreased when cows are fed generously on pasture of good quality, mainly due to changes in substitution rates (Leaver *et al.* 1968, Gordon, 1975, King *et al.* 1977, Bryant, 1981, Stockdale *et al.* 1981,Meijs, 1981, Bryant and Trigg, 1982, Stockdale and Trigg, 1985, Philip and Leaver, 1985ab, Grainger, 1987, Grainger and Mathews, 1989).

At a common level of supplement intake, responses to supplements were greater at low pasture allowances than high pasture allowances and this always occur in associated with the lower substitution rates for herbage at low pasture allowances (Phillips and Leaver, 1985ab; Stockdale and Trigg, 1985; Grainger, 1987; Grainger and mathews, 1989).

The effect of level of supplement intake on yield response is very small (Phillips and Leaver, 1985b). Overall feeding level and the amount of pasture intake, rather than the level of supplement itself are more likely to influence animal production responses (Bryant and Trigg,1982, Stockdale and Trigg, 1982). For instance, Rogers *et al* (1981) reported that for cows grazed on restricted pasture in early lactation, each kg of hay gave a response of an extra 9 gm milk fat directly and 23 gm of extra milk fat over the whole lactation, comparable values for pasture are 42 and 80 gm. of milk fat respectively. King *et al.* (1977a) also reported that when cows grazed on restricted pasture, with a common daily intake of total DM, a linear decline of 0.2 kg of milk or 0.06 kg of milk fat for each kg of hay included in the diet was observed.

Not only the type of supplement used but also level of supplementation affects the concentration of milk constituents. When the ratio of roughage to concentrate is reduced, milk fat concentration falls (Broster *et al.* 1975; Sutton *et al.* 1980). These falls in milk fat concentration are due to the combined effect of an increase in milk yield and decrease in fat secretion. In contrast, when hay is supplemented to cows grazed on lush spring pasture, milk fat concentration is increased (Walsh, 1969), probably because of an increase in fibre in the diet, leading to a change in microbial population typified by reduced number of lactic acid and proprionic producing bacteria and increased number of cellulolytic and fibre digestion bacteria (Rook and Thomas, 1983). In addition, Rook and Thomas, (1983) showed the effect of level of dietary protein on milk protein concentration where conventional diets of hay and concentrate were fed to lactating cows. With diet providing 80% of the digestible crude protein standard for maintenance and milk production, no effect on milk true protein content was evident but a diet providing only 60% of the standard caused a reduction in protein content.

2.3.3.3 Quality of the supplements.

The effects of supplementation on the digestibility of the whole diet is not clear. Arriga-Jordan and Holmes (1986) have shown the depression in digestibility in the diet of cows when concentrate was supplemented (-0.4% per kgDM concentrate). This may be due to a reduction in gastro-intestinal pH which results in a reduction in the digestibility of starch and cell wall carbohydrates (Reid *et al.* 1980). However Eldridge and Kat (1980b) suggested that there was no evidence of any associative effect of hay and pasture on the *in vivo* digestibility of the diet, nor is there any reason to believe that changes in hay quality affects the efficiency of pasture digestion.

Milk yield is unlikely to be affected by the quality of the supplement directly. Effects on milk yield are likely to be due to the differences in herbage intake and total DM intake caused by different qualities (digestibility or ME concentration) of supplements (Astibia *et al.* 1987, Llamas-lamas *et al.* 1987). High digestibility hay contains more soluble DM and has a faster rate of digestion, factors which contribute to the faster passage of the high digestibility hay and results in high intake and better utilisation of DM and fibre (Llamas-lamas *et al.* 1987). Thus DM digestibility of hay was correlated positively with DM consumption (Astibia *et al.* 1987) and animal performance (Worrell *et al.* 1986). Stockdale *et al.* (1981) and King and Stockdale (1981) also suggested that the relative quality of hay compared with pasture determined the ability of the supplement to counteract the effect of underfeeding. Hutton and Parker(1966), Parker (1966) and Stockdale *et al.* (1981) used hay which had a DM digestibility of 53%, 60%, and 63% respectively and came to the conclusion that pasture-hay diet always has a lower nutritive value when compared with pasture only. However, when King and Stockdale (1981) feed hay having a DM digestibility of 70% to cows grazed on pasture of about 64% digestibility, they found that the nutritive value of the hay, in term of production and body condition was similar to that of pasture. Similar results were observed when silage is supplemented. Many experiments report that the quality of silage was positively correlated with milk production (Castle and Watson, 1969, 1970, 1971; Gordon and Murdock, 1978; Castle *et al.* 1980; Gordon, 1980ab; Moisey and Leaver, 1984; Rogers and Robinson, 1984; Phipps, 1987). Castle (1975) and Thomas (1980) concluded in their reviews that the increase in milk yield could be measured by an average of 0.23 - 0.29 kgFCM milk per unit rise in silage digestibility. Rogers (1985) reviewed the effect of silage quality which was supplemented to stall-fed cows given cut pasture and concluded that the cows fed on high quality silage (72.5% digestibility) produced 1.15 kgFCM of milk more than those cows supplemented with low quality silage (67.6% digestibility). However when concentrate was supplemented, Meijs (1986) fed the high starch supplement (12.4 MJME per kgDM) compared with the high fibre supplement (11.7MJME per kgDM) to grazing dairy cows and concluded that the high starch supplement caused a larger reduction in the consumption of herbage, and consequently, a higher milk production was observed when high fibre concentrate was supplemented. Jennings and Holmes (1984), in contrast, reported that no significant difference in milk yield was observed, in cows fed either high (13.6 MJME per kgDM) or low (12.0 MJME per kgDM) quality concentrate. Milk fat concentration, however, was consistently depressed when cows were fed on high quality concentrate (Jennings and Holmes, 1984, Meijs, 1986).

The effect of the quality of supplement on liveweight change was not clear. Rogers (1985) reported that the liveweight change were similar in dairy cows supplemented by either low or high quality silage. In growing cattle, however, Worrell *et al.* (1986) found that the decline in DM digestibility of hay resulted in a decreased in liveweight gain.

In all these cases, however, quality was also positively correlated to intake so how much of the extra milk response was due to quantitative or qualitative effects of the supplements remains unclear.

2.3.3.4 Stage of lactation and level of production.

The extra ME consumed by supplemented cows may cause an increase in milk yield as mentioned before or increase in liveweight gain but in most of the cases a combination of increasing in both milk yield and liveweight gain were observed. The proportion of extra ME consumed, and the extend of partitioning to milk or body tissue synthesis depend largely on stage of lactation. Milk yield response to supplementation may decline as lactation advances (Broster and Thomas, 1981). Broster *et al.* (1969) showed a response of 1.92 kg milk per kg of extra feed DM in early lactation (week 1-9) but only 1.05 kg milk per kgDM supplement in mid lactation and even less in late lactation. Phillips and Leaver (1985a) and Stockdale *et al.* (1981) also reported decreases in milk yield per kgDM supplement eaten as lactation advanced. However, this effect was not observed by Jennings and Holmes (1984) and Phillips and Leaver (1985b) supplementing with concentrate and silage, respectively.

Higher yielding cows showed a greater response to supplement than low yielding cows (Phillips and Leaver, 1985a). Coulon *et al.* (1987) reported a margin of 0.6, 1.2 and 1.6 for cows of a potential of milk yield of < 26 kg, 26-29 kg, and > 29 kg of milk per cow per day, respectively. The greater responses by higher yielding cows have been attributed to the fact that high producing cows partition a greater proportion of total extra ME intake toward milk production and less toward liveweight gain than low producing cows (Bryant, 1981, Grainger *et al.* 1985ab).

2.3.4 Effects on liveweight and body condition.

Supplementation of dairy cows in early lactation always results in either a decrease in liveweight loss or even an increase in liveweight gain, as stated before (section 2.3.3.4). The liveweight response to supplement is likely to be affected by quality and quantity of the supplement rather than the type of supplement (Bryant and Trigg, 1982). However, any positive effect of supplement on liveweight change is likely to reduce the milk response to supplementation because energy partitioning between milk and liveweight is negatively correlated, particularly in late lactation when cows direct proportionally more of their consumed energy into body tissue than into milk production (Rogers, 1985). Many experiments were reviewed and concluded that the mean liveweight response to supplement was 145-150 gm. liveweight per one kgDM supplement (Bryant (1978/79); Stockdale *et al.* (1981); Bryant and Trigg, 1982).

2.4 Factors affecting herbage intake in grazing dairy cows.

2.4.1 The mechanisms of intake control.

The ultimate regulatory centres lie in the brain, the lateral hypothalamic areas which control the pattern of eating behaviour by responding to sensory characteristics of food and by monitoring the onset and decay of satiety after eating (Freer, 1981). The level of satiety,in short term control, is thought to include nervous impulses from stretch receptors in the lining of gut. Changes in body temperature, or circulating hormones together with the indication of fatigue during the meal and changes in the plasma concentration of metabolites arising from digestion and absorption may also set the level of satiety. The monitoring and integration of signals must be a continuous process but the expression of intake control is through the mechanisms which occur during discrete meal in the grazing periods (Freer, 1981). The distribution of these during the day may be affected by social or environmental factors, but the upper limit to their size and frequency appears to be set by the potential energy demand of the animal, depending upon its size, individuality and physiological status (Freer, 1981).

2.4.1.1 Physical regulation of voluntary intake.

In ruminants the bulky and fibrous nature of the foods customarily eaten and their low content of digestible energy emphasised the importance of the physical effect of distension of the gut in limiting voluntary intake (Campling, 1970). Several studies indicate that ruminants fed bulky forage stop eating before they have consumed sufficient nutrients to satisfy their genetic potential for production (Campling, 1970; Bine, 1971; Meijs, 1981). In these situations food intake is determined by two major factors:

<u>The capacity of alimentary tract especially the recticulorumen.</u>

Campling (1970) reported that the intra-ruminal accumulation of food causes an immediate decrease in food intake while the removal of the swallowed diet encourages the animal to eat for very much longer than normal.

A direct association between the voluntary intake of food and the size and weight of the empty recticulorumen has been found (Camling, 1970). The principle determinant of rumen capacity is the size of animal, thus when food of a relatively low digestibility is given to animals, intake will be generally related to liveweight (Bines, 1971). The size of the rumen, in addition, is limited by the size of the abdominal cavity, which appears to be limited in the extent to which it can stretch (Campling, 1970; Bines, 1971).

The size of growing foetus(es) and deposition of fat within the abdominal cavity may reduce the capacity of the recticulorumen, thus reduce the intake in ruminants (Campling, 1970; Forbes, 1971; Forbes, 1980). The mechanism by which the stretch receptors in the rumen wall will limit food intake in ruminants is not completely understood but the possible mechanism can be by discomfort, by stimulation of the humoral intake regulating factors or by mechanism of rumination (Van Soest, 1982).

As the physical controls are primarily related to the capacity of the digestive tract, (Freer, 1981) to the fibre content of the feed and to the rate of degradation and passage, therefore, the indigestible fraction of the DM is a major physical factor limiting intake (Raymond, 1969; Waldo, 1986). For example, Baile (1975) reported that higher bulk density gains are likely to be consumed in larger amount in meals with low frequency , while low bulk density straw diets are likely to be eaten in more frequent small meals.

Rate of disappearance of digesta.

The rate of disappearance of digesta from the recticulorumen normally depends upon the rate at which the food is broken down chemically by the process of digestion and the rate at which the undigested residuals of the food are broken down physically, before they can move from rumen (Campling, 1970; Meijs, 1981); these are together with the capability of muscular contraction of the gut and size of the recticulo-omasum orifice (Ulyatt *et al.* 1985; Korver, 1987). Retention of feed in the recticulorumen allows substantial microbial fermentation to take place, with over 60% of OM digestion occurring in the recticulorumen (Ulyatt *et al.* 1985). Retention time is influenced by a number of dietary factors such as an amount of feed consumed, forage physical form, physical content, physical nature of the fibre and forage:grain ratios (Freer, 1981; Shaver *et al.* 1986). The rate of enzymic digestion by rumen microbes is closely related, in general, to the chemical composition of the feed (Bines, 1971). For example, when inferior roughage is supplied, addition of nitrogen to the rumen increases microbial activity, rate of breakdown and voluntary intake (Campling, 1970; Bines, 1971).

Factors which are involved in the movement of particles from the recticulorumen include particle size, particle density, particle reduction rate, feed cell wall content, feed DM percentage, pH and osmotic pressure, strength and frequency of ruminal and abomasal contraction (Shaver *et al.* 1986).

Undigested material simply passes through the recticulo-omasal orifice after being reduced to fine particles (< 2.0 mm). The critical size of the particle is relatively insensitive to change in digestibility, physical content of the feed and consequently feed intake. For instance, Campling (1970) stated that presenting ruminants with ground roughage lead to a higher voluntary intake than when the same roughage is offered in a long form. The rate of passage of the small particles is increased, resulting in higher voluntary intake but lower digestibility (Meijs, 1981). Shaver *et al.* (1986) however, concluded that the amount of material passed per contraction of recticulorumen rather than the particle size is probably more an important factor affecting voluntary feed intake.

2.4.1.2 Metabolic regulation of voluntary intake.

The control of food intake by animals can be considered as a component of the homeostatic regulation of energy balance between the animal and its environment (Baumgart, 1970; Baile and Forbes, 1974; Baile and McLaughlin, 1987). The energy balance is depicted as a controlled system. Gut filling, digestion and metabolism following the consumption of a meal produce feed back signals. The ventromedial hypothalamus may provide the set point at which feed back signals will result in satiety. Environmental temperature influences the integration of signals , thus, influencing the final signal and feed intake (Baumgardt, 1970). Feed back signals may be sensed in the rumen wall, liver, adipose tissue and/or peripheral and cerebrospinal fluid, but final integration probably occurs in the hypothalamus (Baumgardt, 1970).

By contrast with non-ruminants, glucose is not likely to be an important feed back signal in ruminant (Baile and Mayer, 1970; Bines, 1971; Van Soest, 1982). Proprionate and acetate are recognised as possible signals of satiety in the ruminants (Baile and Mayer, 1970) whereas, butyrate is possibly less important. The role of lactate is controversial, probably depressing the mobility of the stomach (Forbes, 1980).

The role of hormones as signals of food intake is not clear. The possible role of hormones like estrogens, insulin, growth hormone and others has been discussed by several authors (Forbes, 1980; Wangness, and Muller, 1980; Baile *et al.* 1983; Brockman and Laarveld, 1986).

2.4.1.3 Mechanical processes of grazing.

Mechanical processes of grazing play a key role in the mechanisms of control of the grazing animals (Poppi *et al.* 1987). Pasture intake (I) in grazing animals is the product of the time spent grazing per day (GT, minute), rate of biting (RB, bite per minute) and the weight of pasture eaten per bite (IB, gmOM per bite) (Allden and Whittaker, 1970; Holmes and Wilson, 1984; Hodgson, 1985) so that:

$$\text{Pasture intake (gmOM per day, I)} = GT*RB*IB$$

The time spent grazing (GT) in a 24 hours period is influenced by the food requirements of the animal, the amount and distribution of the vegetation and the rate at which animal eats (RB). However, Stobbs (1973), Hodgson (1981) and Poppi *et al.* (1987) suggested that the variation in bite size (IB) is usually greater than variations in either RB or GT and appears to be the most sensitive component to variations in pasture allowance and sward conditions (bulk density, sward height, shearing strength, sward structure and the accessibility of preferred components). Since any compensating components in RB or GT are usually limited, therefore, IB is likely to be a major determinant of daily herbage intake (Leaver, 1985, Hodgson, 1985). However, supplementary feeding seems to depress herbage intake through the reduction in grazing time (Phillips and Leaver, 1985ab).

During feed shortages, on either range of pastures, more time will be spent grazing, so that the number of bite per day will probably increase but intake per day will decrease, as a result of a reduction in bite size (Hodgson, 1977; Arnold, 1986). The grazing time (GT) of the cow is in the range of 8 - 11 hours per day with the mean value of about 9 hours (Arnold, 1981; Leaver, 1985; Arnold, 1986) beyond this range grazing would interfere with rumination and other behavioural requirements such as the period of rest and drinking.

Several experiments have shown a reduction in grazing time between 9 to 38 minutes per kgDM concentrate supplement eaten by grazing cows (Sarker and Holmes, 1974; Journet and Demarquill, 1979; Arriga-Jordan and Holmes, 1986) including silage (Phillips and Leaver, 1985b) or hay (Phillips and Leaver, 1985a).

Rumination time, in addition, is related to the cell wall content of the forage (Van Soest, 1982). Shorter ruminating time has been found for a ground pellet hay compared with long or chopped hay (Shaver *et al.* 1986). Rumination time was significantly increased when hay or silage are supplemented in grazing animals (Phillips and Leaver, 1985ab).

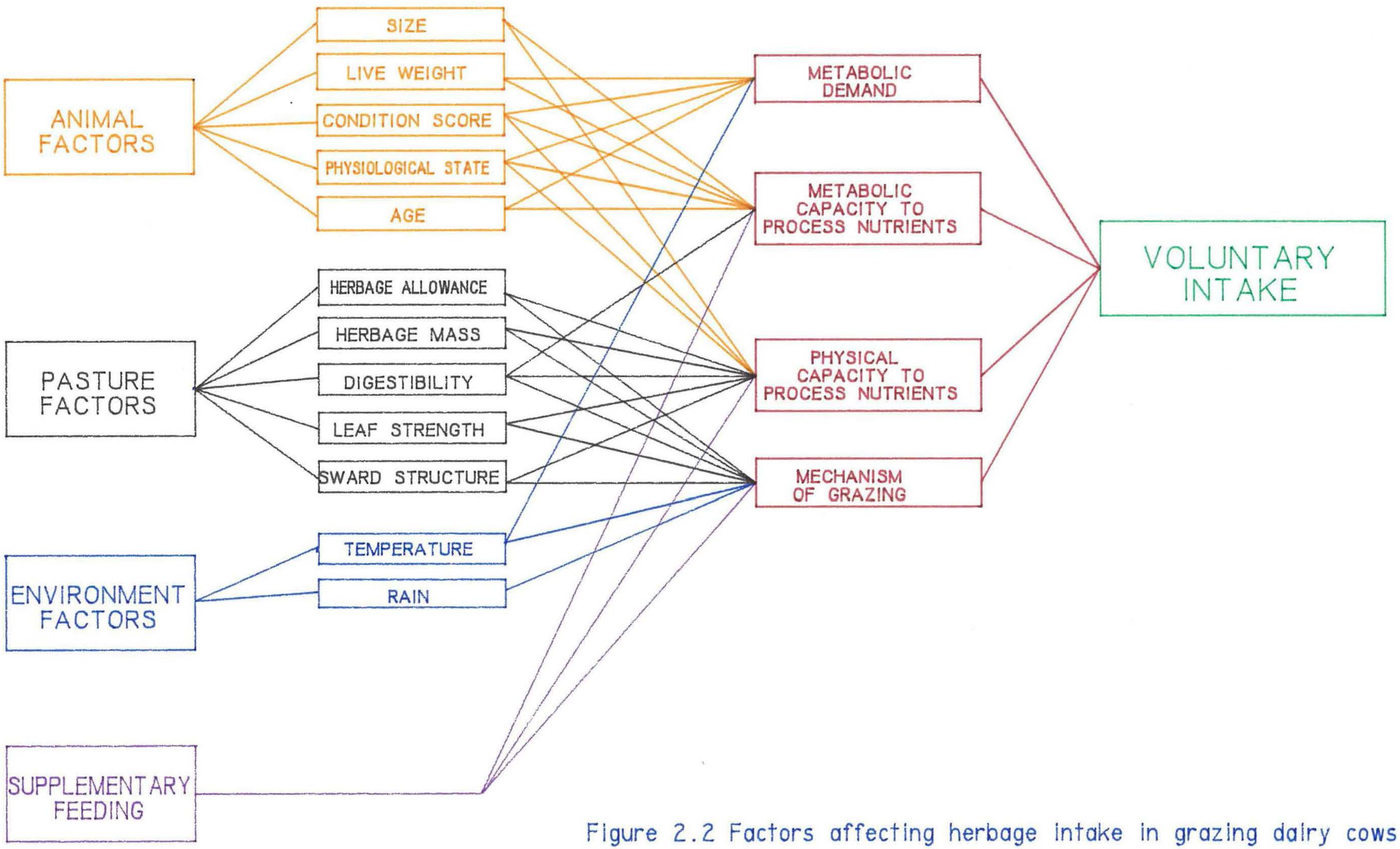


Figure 2.2 Factors affecting herbage intake in grazing dairy cows

2.4.2 Voluntary food intake when the quantity of feed offered is not a limiting factor.

It is generally accepted that the level of feed intake per cow is directly related to milk production (King *et al.* 1980; Grainger *et al.* 1982; Hodgson, 1982; Holmes *et al.* 1985; Mitchell, 1985), where intake is defined in terms of the level of digestible nutrients intake in relation to maintenance (Van Soest, 1982). Factors which affecting feed intake, therefore, directly affect milk production per cow. Feed level can be imposed upon the animal by external circumstances such as availability of feed when level of intake can be varied from zero upward to a maximum intake which is accepted by animals. These are particularly relevant to stall feeding. In grazing conditions, other physical factors come into to play. Meijs (1981) classified the factors which affect the voluntary intake of grazing ruminant into 3 broad groups. These are animal factors, plant factors and environmental factors. These will be discussed in detail later (sections 2.4.2.1, 2.4.2.2, 2.4.2.3).

Intake of the feed itself is regulated and limited by the requirements of the animal physiology which influences the animal ability to consume feed, to accommodate and digest it in the digestive tract and metabolic factors which influence the animal requirements for nutrients and its ability to absorb and metabolise the nutrients (Baumgart, 1970; Bines, 1971). For most cases in grazing animals, the regulation of food intake is determined by the inter-relationship between these two factors and the mechanical processes of grazing (Hodgson, 1977; Poppi *et al.* 1987). However it has to be realised that these mechanisms are complex and many of the plant factors are interrelated under most conditions of grazing experiments, as shown in Figure 2.2.

2.4.2.1 Factors which originate from within the animal.

Size, Liveweight, Body condition, Age and Genotype of the animal.

It is clear that when animals receive feed of a high digestibility an upper limit of feed intake is set up by the animal's potential requirement for dietary energy which is related generally to the liveweight of the animal (Holmes and Wilson, 1984). When animals receive low digestibility diets, however, an upper limit of feed intake is set up by the distension of alimentary tract which is related generally to size of the animal (Bines 1979; Meijs, 1981; Holmes, 1987). Therefore, voluntary feed intake is positively correlated to liveweight and size of animal. Heavier animals eat more (Bines, 1976, 1979; Meijs, 1981) because of their higher nutrient requirements (Braumgardt, 1970) and may also because of their larger digestive tracts.

Voluntary feed intake is also related to body condition score (Forbes, 1980; Broster and Thomas, 1981; Grainger and McGowan, 1982). For example, at any given size for an animal, voluntary feed intake in a fat animal will be less than in a thin animal. This may be controlled by physical mechanisms since the larger amount of voluntary intake in thinner animal is probably associated with the increase in abdominal space available for the gut in the thinner animal (Freer, 1981, Holmes, 1987). In contrast, the reduction in voluntary intake of a fat animal may be attributed to the restricting effect of abdominal fat on the rumen. However, in long term regulation of energy balances, the effect of body condition on voluntary feed intake may be regulated by metabolic mechanisms, since Meijs (1981) indicated the negative correlation between body fat and feed intake.

In addition to the effect of body weight, the age of an animal influences its feed intake (Forbes, 1986). For example, Meijs (1981) reported that herbage OM intake per unit liveweight in calves was about 43-76 percent higher than in adult, because the growing animal has larger energy requirements than the non-pregnant non-lactating adult animal.

There is considerable variation between the voluntary intake of animals, even of the same size, age and body condition (Holmes, 1987). Differences in milk production at the same stage of lactation which results from genetic potential, may lead to differences in herbage intake (Meijs, 1981). In several grazing experiments, a strong positive relationship between herbage intake and daily milk production has been shown. Holmes and Wilson, (1984) stated that cows which are genetically capable of producing larger quantities of milk are likely to eat larger quantities of feed. Differences of 20-30 percent milk production are associated with differences of 5-15 percent in voluntary feed intake (Holmes and Wilson, 1984).

Physiological state of the animal.

In theory, the upper limit of voluntary feed intake is set by the animal's potential energy demand, which includes basal metabolism, the energy required to graze and chew herbage and the capability for either storing energy body tissue or secreting it as milk (Freer, 1981). This demand is obviously related, on a broad scale, to the size and physiological state of the animal (Freer, 1981).

Effect of pregnancy:

The animal's demand for nutrients increases with advancing pregnancy (Forbes, 1970, 1971; Meijs, 1981). However her voluntary food intake does not increase proportionately during the latter stage of pregnancy (Freer, 1981; Holmes and Wilson, 1984). It is generally accepted that the intake falls as parturition approaches regardless of the type of diet offered (Forbes, 1971; Journet and Remond, 1976; Meijs, 1981, Weston, 1982). This may due to the progressive increase in the size of the conceptus during pregnancy. The space occupied by the conceptus as well as the hormonal changes such as the increase in placental secretion of oestrogens may limit food intake (Forbes, 1971; Baile and Forbes, 1974; Bines, 1979; Freer, 1981)

Effect of lactation:

An increase in animal requirements for dietary energy is usually followed by an increase in voluntary feed intake (Freer, 1981, Holmes, 1987), regardless of type of diet. Arnold (1986) reported that during early lactation the grazing time was about 7-12 percent higher than for non-lactating animal at all levels of pasture availability. On average, lactating cows consume 42% more than non-lactating cows (ARC, 1980). It has been suggested that the greater intake was probably due to hyperthophy of the alimentary tract (Campling, 1970; Leaver, 1985) or the endocrine changes associated with the onset of lactation (Campling, 1970; Freer, 1981), but the mechanisms are not clearly understood. The positive relationship between the level of milk production and voluntary feed intake was shown by several studies (ARC, 1980; MAFF, 1984; Bines, *et al.* 1987). Milk production rises rapidly immediately after parturition and usually reaches a peak between day 30-50 and thereafter decline steadily, whereas food intake increases to reach a peak at an average of 16 weeks after parturition, (Bines, 1976, 1979) developing a lag of energy intake balance (Meijs, 1981). It has been suggested that the factors are of a physical origin (Bines, 1976) such as abdominal fat (Journet and Remond, 1976), delay of hyperthophy of gut wall, liver (Bines, 1979), alimentary tract or endocrinological factors (Meijs, 1981).

Taking the whole lactation period into account, however, feed intake is likely to show a positive relationship with milk production (Owen, 1988). In conclusion, a peak value of voluntary intake may be determined by hormonal levels, genetic merit, through its effect on level of production, the level of nutrition during pregnancy and the number of offspring (Freer, 1981).

2.4.2.2 Factors affecting voluntary intake which originate from sward characteristics and grazing management.

Grazing animals have to select and harvest their diets from mixed populations of forage plants which vary, within and between individuals, not only in all those structural features that determine the ease of harvesting and the rate of disappearance of digesta from the gut but also the range of other attributes that affect acceptability of the material through smell, taste or tactile stimuli etc. (Freer, 1981). Thus, there are several factors which originate from the sward itself which are involved in the voluntary intake of grazing animals. Those are:

<u>Herbage allowance:</u> **(Total quantity of pasture made available per day)**

Herbage allowance is the most important factor which affects herbage intake in grazing animal, as it influences the mechanical processes of grazing, particularly in rotational grazing systems (Le Du *et al.* 1979; Cambellas and Hodgson, 1979; Bryant, 1980; Glassey *et al.* 1980; Mitchell, 1985; Holmes, 1987).

The relationship between herbage allowance and herbage intake is generally curvilinear (Hodgson, 1976). An animal will be able to achieve its maximum herbage intake if it is offered an unlimited supply or allowance (Holmes, 1987). Increases in allowance have very large effects on intake at the lower level allowances; further increases in allowances have smaller effects on intake at levels of intake which are close to the maximum voluntary feed intake for the animal (Hodgson, 1976) as shown in Figure 2.3. Herbage OM intake approaches its maximum at an allowance 4 times greater than the amount actually consumed (Hodgson, 1976) and starts to decline markedly when herbage allowance is less than twice the intake for lactation cows.

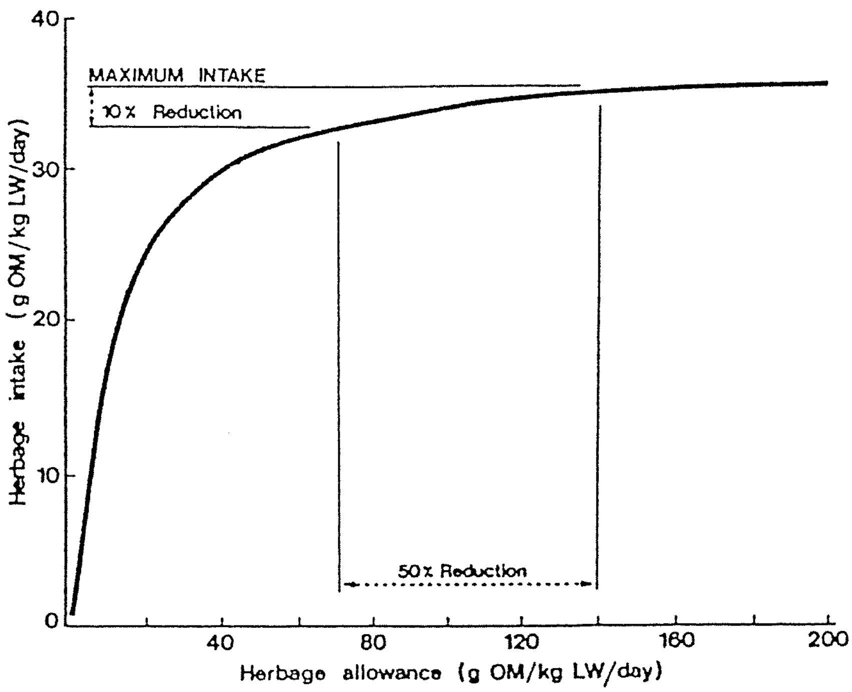


Figure 2.3 Relationship between daily herbage allowance and daily herbage intake.

As herbage allowance increases, so too does herbage intake, but at the proportionately slower rate. Therefore residual herbage mass also increases as herbage allowance is increased (Holmes, 1987). Thus, there is a relationship between post grazing herbage mass and pasture intake. However, the relationship between intake and post grazing herbage residual may be affected by pasture species (Stockdale, 1985), herbage mass (Combellas and Hodgson, 1979), season (Holmes, 1987) and quality (Hoogendorn, 1987) Holmes (1987), therefore, recommended that OM intake can be predicted more reliably from pasture allowance than from post grazing herbage mass.

Herbage mass.

The amount of herbage present per unit area and its distribution in space, have been acknowledged to be an important extrinsic factor limiting herbage intake through their effects on the ease of prehension of herbage (Baker, 1976). Herbage mass is even more important for set stock grazing system because it effectively controls the quantity of herbage available for grazing each day, whereas herbage allowance is more important for rotationally grazed cows. In a rotational system, area grazed and pasture availability per day is set by management strategies, whereas pasture availability and area grazed in a set stocked system is set by the ability of the animal to graze and the herbage mass (tonne per hectare). In dairy cows, the range of RB (rate of biting, bite/minute) between 55 - 65 bites per minute was noted (Chacon *et al.* 1976) with GT of 8 - 11 hours per day (Arnold, 1981) and IB of 0.31 - 0.71 gmDM per bite, the variation of IB observed may be caused by the differences in sward condition and structure (Stobbs, 1974). Area grazed in set stock animals could, therefore, be calculated from multiplying the area grazed per bite and GT and RB. Intake depends largely on area grazed and herbage mass, since herbage mass would determine IB in set stock animals. Rattray *et al.* (1978) reported that as pasture mass and height decrease, at the same pasture allowance, pasture will become increasingly difficult for the animal to harvest, consequently herbage intake declines as well as animal performance (Baker, 1976). Hodgson (1977); Jameison and Hodgson (1979) and Forbes and Hodgson (1985) found that the increase in herbage mass per unit area causes an increase in daily herbage intake, however, a decrease in intake may also occur when the herbage mass exceeds an optimum value. Perhaps the effect of herbage mass on pasture intake may be confounded by herbage quality (Baker, 1976; Holmes, 1987). Alternately, Hodgson *et al.* (1977); Reardon (1977); Bartholomew *et al.* (1981); Meijs, (1982) have reported that no changes in herbage intake was observed with increasing pasture mass. In general term, Holmes (1987) stated that the DM intake is not affected by variation in pregrazing pasture mass in the range of 2-4 tonne DM per hectare. It is possible that a lower herbage mass, eg. 1.5 tonne DM per hectare, might reduce pasture intake since it is difficult for a cow to harvest the herbage in very short and sparse swards because it is limited by the mechanics of it's mouth and tongue, consequently IB has been reduced. Herbage intake will decrease markedly if the pasture height decreases below 7 cm (Le Du *et al.* 1981). Poppi *et al.* (1987) also stated that pasture height is likely to be the best predictor of bite size and intake. However, it is too naive to think that bite size and intake will be determined by pasture height alone since the rate of intake can decline with very tall pastures also. Therefore, at very high pasture mass eg. 5 tonne DM per hectare intake might be reduced due to the increase in low quality stem and dead material (Stobb, 1973; Combellas and Hodgson, 1979).

Pasture quality.

Pasture quality is a nutritional factor which influences herbage intake. Digestibility is the measurement most often used to describe nutritive value (Poppi *et al.* 1987). The botanical composition of herbage and the quantity and digestibility of the leaf, stem, inflorescence and dead components have a major effect on pasture quality and intake (Hodgson, 1977; Poppi *et al.* 1987). Smetham (1977) also suggested that the most important measurement of pasture quality for the ruminant is digestibility since digestibility seem to be the most important factor affecting animal performance.

DM intake by grazing cows is not affected consistently by the digestibility of pasture. When pasture allowance was not restricting intake, Hodgson (1977) showed a linear and constant rate of increase in herbage intake over a range of digestibility up to OM digestibility of 80-83%. However, Meijs (1981) suggested the curvilinear relationship between DM intake and DM digestibility with the point of inflection occurring at digestibility between 65-70%. Figure 2.4 depicts the relationship between digestibility, dry matter and energy intake for the ruminant. When feeds are of high digestibility, voluntary intake is probably limited by the energy requirements of the animal and its ability to mobilise and absorb nutrients, then the quantity eaten decreases with digestibility increase. In animals grazed on pasture, the linear relationship between voluntary intake and digestibility can be up to the pasture digestibility of 80%. This may be because a high digestibility pasture contains a large proportion of green leaf and small proportion of stem and dead material. These would make the pasture attractive to grazing stock and these pastures are easy to prehend. Therefore, intake may continue to increase with increases in herbage digestibility up to 80%. It is very important that no one factor (physical or metabolic) needs explain intake regulations and that a combination of factors both physical and metabolic are integrated to control *ad libitum* intake (Poppi *et al.* 1987). The components of pasture quality described in the following section are most likely to have an effect on herbage digestibility and the animal performance.

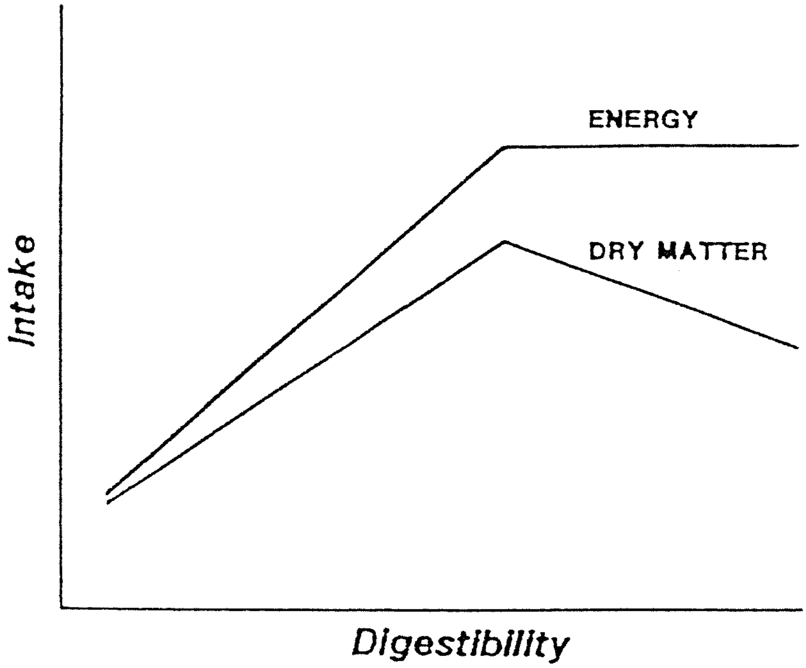


Figure 2.4 Relationship between digestibility, dry matter and energy intake for ruminants receiving varying ratios of hay to concentrates.

Botanical composition:

The quality of pasture can be altered by changes in species comprising the sward (Holmes and Wilson, 1984). Generally legumes are of higher digestibility than grasses with intake of legumes being up to 40% greater than grasses (Poppi *et al.* 1987). The higher feeding value of legume, contribute to higher milk yields per cow (Rogers *et al.* 1982). When grazed on mixed swards, dairy cows are generally able to select herbage of higher average digestibility than that on offer. The extent to which this occurs is dependent on the amount of feed on offer and its botanical composition (Leaver, 1985). It has been reported that selected herbage may be 3-10% higher in digestibility than the average of that on offer (Taylor and Deriaz, 1963; Le Du *et al.* 1981).

The maturation of herbage and dead matter content:

During the maturation of herbage the proportion of cell wall material progressively increases but more important, the potential digestibility and rate of digestion of this material decrease (Holmes and Wilson, 1984). The changes in composition of cell wall involving lignin and possible silica, limit the potential extent of digestion (Freer, 1981). This results in a 2-3 folds increase in the time required for chewing of food particles before their passage out of the rumen; consequently herbage intake decreases (Freer, 1981).

The reproductive growth surge in pasture often results in an undesirable accumulation of dead material which lowers pasture quality over the summer period (Goold *et al.* 1985). The dead matter content of pasture is negatively correlated with digestibility (Rattray, 1978), herbage intake (Holmes, 1987; Poppi *et al.* 1987; Rattray *et al.* 1987) and milk production (Thomson *et al.* 1984).

Leaf/stem ratios:

At a leafy or vegetative state of growth, grass species in a pasture contain relatively large amounts of digestible cell contents (Osbourn, 1980; Waghorn and Barry, 1987). Poppi *et al.* (1987) reported that, for material of common digestibility, the intake of leaf is 100% greater than stem. Rattray *et al.* (1987) illustrated that grazing sheep show a preference for green leaf and reject pseudostem and dead material. However, as a plant matures, the proportion of leaf to stem decreases, together with digestibility (Terry and Tilley, 1964; Bryant, 1981). These will result in a decrease in voluntary intake by grazing ruminants (Hodgson, 1977; Holmes, 1987; Poppi *et al.* 1987).

Breaking strength:

Intake per bite might be expected to depend on the breaking strength of plant material (Poppi *et al.* 1987). Significant differences in leaf strength have been found between species and varieties of pasture (Evans, 1967). Poppi *et al.* (1987) stated that the size of bite may be limited by the maximum force the animal is able to exert in prehending a bite, thus, intake per bite could decrease as tensile strength of leaves increase. It was found that differences in stem strength may be associated with differences in palatability, animals preferring species with lower leaf strength (Evans, 1964). Thus, it may implied that the choice by an animal of leaf or stem may be related to its shearing strength (Poppi *et al.* 1987). Sheep grew faster when grazed on a pasture with a lower leaf strength, than those on a pasture with a higher strength (Evans, 1967).

2.4.2.3 Environmental factors.

Voluntary intake is generally decreased in hot climates and increased in cold climates (Holmes, 1987). It was reported that grazing sheep increase their intake by 40-60% where subjected to cold conditions following shearing because of an increase in the rate of heat production required to maintain body temperature (Forbes, 1986). Very high temperatures depress intake and prolonged exposure to radiation may affect cattle deleteriously (Weston, 1982). However, the critical temperatures will depend on the breed and the age of the animal as well as production level, physiological state, and adaptive behaviour (Meijs, 1981).

Most experiments investigating temperature/feed intake/milk production relationships have been undertaken overseas, but there is no evidence that temperature extremes have any influence on feed intake and milk production in New Zealand.

In New Zealand, however, there is evidence that herbage intake at particular pasture allowance may be different at different seasons (Holmes, 1987). The animal may consume smaller quantities of pasture in summer than in spring. This may be explained by the differences in pasture composition and digestibility with different seasons rather than temperature (Holmes and Wilson, 1984; Holmes, 1987).

Social facilitation of feeding is known to occur in both sheep and cattle (Forbes, 1986). Coppock *et al.* (1972) found that lactating cows ate 7% more feed when grouped than when feed separately. However, social interaction do not necessarily facilitate feeding if animals are in confined space (Forbes, 1986).

2.5 A summary of the effects of supplementary feeding on grazing lactating cows.

Based on data cited by Holmes *et al.* (1981), the consumption of an additional one kg of dry matter (11 MJME) from a supplementary feed should theoretically cause; (a) the production of an extra two kg of milk or 90 gm. milk fat or (b) an increase of liveweight by 300 gm, or (c) a decrease of 11 MJ of ME in the cow's intake of grazed pasture, or (d) some combination among a, b and c. Evidence reviewed by Bryant and Trigg (1982) and Wilson and Davey (1982) showed that one kg of extra dry matter, fed as concentrates, silage or hay in early lactation actually produce; (a) an extra 0.5 kg milk, or 25 gm. milk fat, plus (b) an extra 150 gm. liveweight and (c) an increase in residual herbage mass, due to a decrease in grazed herbage intake.

In general, the feeding of supplements causes a decrease in the quantity of herbage eaten, due to the substitution of pasture by supplements; for example, and extra of one kg concentrate eaten by a cow will increase its total intake only 0.3 to 0.5 kgDM (Bines, 1979). This effect have been already discussed in detail in sections 2.3.1.1, 2.3.1.2, 2.3.1.3 and 2.3.1.4.

The reduction in pasture intake when supplements are fed is partly by the reduction in grazing time (GT) since the animal requires more time to ruminate when they are supplemented, particularly with hay or silage (Phillips and Leaver, 1985ab). Levels of satiety are normally set through metabolic regulation controls when high energy supplements such as concentrates are fed, whereas the physical regulation control seems to be the major regulation limiting pasture intake when low energy supplements such as conserved forage are fed (Brumgardt, 1970; Campling, 1970).

2.6 Objective of the study.

During winter and early spring, supplementary feed, particularly silage and hay are commonly given to lactating cows which are grazing on restricted pasture. On "market milk" farms, in particular, where milk is produced all year round for local consumption, supplementary feeds are essential components of winter diet. The digestibility of a feed is known to be an important feature of its feeding value. Hay normally used on dairy farms can vary in digestibility between 50%-65% with ME concentration of 6.7 - 9.0 MJME per KgDM (Rogers, 1985). However, there has been no experimental work in New Zealand to study the effect of the digestibility of a supplementary feed on its feeding value for lactating cows.

The present study, therefore,was carried out to assess the effect of digestibility of hay supplemented for spring calving cows in early lactation. The effects of hay digestibility on pasture and hay consumption, total DM and ME intake, residual herbage mass, milk production and composition and liveweight and body condition score change were investigated and discussed.

CHAPTER 3

MATERIAL AND METHODS

The 30 day grazing experiment was conducted at Massey University's Dairy Cattle Research unit, Palmerston North, New Zealand during September - October, 1988.

The unit is a seasonal supply farm of 45 ha, divided into 45 paddocks. The soil type is Tokomaru silt loam, consisting of a 15-30 cm layer of heavy silt overlying a mottled clay loam. The paddocks of the whole unit have been drained with tile and moles and have been fertilised with 350 kg potassic superphosphate and 50-100 kg urea per hectare per year. The surplus grass during the year is conserved as silage (early conservation) or hay (late conservation). The pastures consist mainly of perennial ryegrass (*Lolium perene*) and white clover (*Trifolium repens*) with small proportions of cockfoot (*Dactylis glomerata*), phalaeis (*Phalaris* spp.) and prairie grass (*Bromus willdenowi*).

The common abbreviations presented in this thesis are given in Table 3.1

Table 3.1 Common abbreviation

LW	Liveweight
CS	Body condition score
HM	Herbage mass
RHM	Residual herbage mass
DMI	Dry matter intake
IB	Intake per bite
RB	Rate of biting
GT	Grazing time
DM	Dry matter
DMD	Dry matter digestibility
OMD	Organic matter digestibility
DOMD	Digestible organic matter in the dry matter
GE	Gross energy
ME	Metabolisable energy
MEI	Metabolisable energy intake
VFA	Volatile fatty acid

3.1 Animal and Treatments.

Two treatments were imposed during the experimental period, with cows which grazed on a restricted allowance of pasture at night time. Supplementation was during the day time with either low digestibility hay (LH) or high digestibility hay (HH). Both hays were purchased in bales, each weighting approximately 20 kg. The hay were selected on the basis of physical appearance, with the "high digestibility" hay containing a higher proportion of leaf than the "low digestibility" hay. In other respects the two hay types were similar, and of good palatability. Sixteen high producing Friesian dairy cows were randomly divided into two groups each of 8 cows on 15th September 1988. Details of the cows used in the experiment are given in table 3.2

Table 3.2 Data for the cows before the start of the experiment (mean ± SE).

mean value for :	Low digestibility Hay	High Digestibility Hay
Calving date	17 August	23 August
days in lactation	29 ± 11	25 ± 9.0
Milk yield	19.8 ± 2.7	20.0 ± 3.0
Fat yield	0.99 ± 0.17	1.03 ± 0.24
Protein yield	0.74 ± 0.09	0.72 ± 0.14
Lactose Yield	0.99 ± 0.14	0.99 ± 0.17
Fat percentage	5.24 ± 0.67	5.14 ± 0.88
Protein percentage	3.80 ± 0.50	3.63 ± 0.30
Lactose percentage	4.99 ± 0.26	5.08 ± 0.16
Liveweight	404 ± 54.00	408 ± 50.00
Condition score	4.4 ± 0.6	3.8 ± 0.3

3.2 Animals, pasture and hay supplementation.

The experimental cows were selected, according to their milk yield, age and date of calving. Before the start of experiment, all cows grazed together with the main herd at a generous herbage allowance. At the start of the experiment, the experimental cows were weighed and condition scored. For the first week of the experiment, the cows were separately fully fed by either low or high quality hay in the barn during day time while they were still allowed to graze together with the main herd during night time.

After morning milking, for the experimental period, each group of the cows was kept in the barn in individual stalls, with constant access to water and feed in individual troughs. Each cows was fed on either high or low quality hay. The quantity offered and the hay left uneaten was weighed, dry matter percentage was estimated for hay both before being offered to the cows and for the hay left uneaten by the cows in the afternoon. Thus, the DM consumed could be computed.

The cows were given one fresh strip of pasture every 24 hours after the afternoon milking. Each paddock was divided longitudinally into two equal areas, one area for each treatment group. These areas were further subdivided into 6 - 8 breaks depending upon size of the paddocks and estimated pregrazing herbage mass in order to offer the pasture allowance of 12 kgDM per cow per night. Each break was grazed by either low or high digestibility hay group nightly, and back grazing was prevented by mean of an electric fence.

The experimental description is summarised in table 3.3

Table 3.3 Summary of experimental description.

Pre experimental period	All cows grazed together with the main herd at generous herbage allowance.
Day 0 - 7	All the experimental cows were weighed at the beginning of the experiment. To allow the animals become accustomed to hay feeding, they were stall fed with either low or high quality hay. All of them were still allowed to graze with the main herd during the night time.
Day 8 - 27	Experimental cows grazed in two separate groups at the nominal herbage allowance of 12 kgDM per cow per 12 hour period of grazing during night time. The cows were ad-libitum stall fed with either low or high digestibility hay during day time in the barn.
Day 28 onwards	The cows were returned to graze with the main herd at a generous herbage allowance. Cows'performance were recorded for further 5 weeks
Day 30	The cows were weighed after two days from the termination of the experiment (in order to ensure that the ingested hay was already removed from the digestive tract and to allow for equilibration of gut fill).

To measure the *in vivo* digestibility, hay which was collected from each bale during the experiment was fed to 6 sheep at maintenance level (0.5 MJME/LW 0.75). More detail of the method in section 3.3.2.1.

3.3 Measurements.

3.3.1 Pasture Measurement.

The pasture was cut before and after grazing on 9 occasions during the whole experiment. The technique adopted (Walters and Evans, 1979) on each occasion involved cutting to 5 quadrants ($0.1875m^2$ each) to ground level for each treatment. A sheep shearing hand piece powered by a mobile petrol motor was used by one operator to cut the herbage samples.

After cutting, the samples were washed to eliminate all the soil and dung and dried at 70 - 80 C for 36 hours and weighed. A subsample from each pregrazing cutting at each period was collected, bulked and frozen for later chemical analyses.

These samples, collected from each pregrazing cutting, were dried at 70 - 80 C for 72 hours, then ground and passed through a 2 mm sieve. Those samples were subjected to analysis for :

a) Gross energy concentration - MJ/kgDM (Adiabatic calorimeter bomb)

b) Nitrogen concentration - gm/kg (Kjeldahl)

c) Ash concentration - gm/kg (500 C)

d) In vitro digestibility (Roughan and Holland, 1977)

The calculation of crude protein was made by using the equation :

$$CP = 6.25 N$$

where

CP = crude protein (%)

N = nitrogen concentration in the dry matter

3.3.2 Hay measurement.

The quantity of hay offered to each individual group of cow was recorded as well as the quantity of the residual hay left uneaten each day. Samples were taken from every bale of the hay offered to the cows; samples were also collected from residual, uneaten hay. Those samples were dried at 70 - 80 C for 24 hours to determine DM percentage. Hay intake (kgDM per cow per day) was subsequently computed from these data. The samples of hay taken from each bale were bulked over periods of four weeks, ground and passed through a 2 mm sieve, then subjected to the same analyses previously described for the pasture (see above).

3.3.2.1 *In vivo* digestibility of hay.

The *in vivo* digestibility of the hay offered was evaluated using 3 sheep for low quality hay and 3 sheep for high quality hay. Those sheep were fed hay collected from every bale used during the experiment. The nutritional level was planned to be at maintenance; the ranges from 0.43 - 0.60 MJME/kg$^{0.75}$/day are recommended (MAFF,1975; ARC, 1980). However, the value of 0.5 MJME/kg$^{0.75}$/day was selected. The animals were allowed to become accustomed to the hay as the sole feed for 14 days before collection of the faeces began. From day 15 and onwards throughout the 14 day experiment, hay offered and residual hay and faeces were weighed daily. The faeces were bulked over for 7 days and stored at -4 C. Hay samples were dried at 70 - 80 C for 36 hours while faeces samples were freeze dried for 7 days. Those samples were then subjected to the laboratory analysis described above.

Calculation :

The *in vitro* digestibility of the feed was measured using the technique described by Roughan and Holland (1977). The value reported were DMD, DOM, and DOMD.

where

$$\text{DMD (\%)} = \frac{\text{DM intake - DM faeces} * 100}{\text{DM intake}}$$

$$\text{DOM (\%)} = \frac{\text{OM intake - OM feaces} * 100}{\text{OM intake}}$$

$$\text{DOMD (\%)} = \frac{\text{Food OM - Faeces OM} * 100}{\text{Food OM}}$$

The DOM values can be converted to DOMD values if the ash content of the food is known:

$$\text{DOMD (\%)} = \frac{\text{DOM (\%) (100 - Ash \%)}}{100}$$

The digestible energy and metabolisable energy concentrations of the hay and pastures were calculated from the values for DOMD, from the equation;

$$\text{DE} = 0.19 \text{ DOMD \% (MJ/kgDM)}$$

This equation assumes that the energy value of digested organic matter (DOM) is 19 MJ/Kg DOM (MAFF 1975 , ARC 1980).

When conserved pasture was supplemented to animals grazing on pasture, the digestibility of the two feed were assumed to be independent and no interaction (Eldridge and Kat, 1980a, Corbett, 1978). Thus, the ME intake in an animal supplemented by conserved pasture can be estimated directly from in vitro digestibility of the diet as :

$$\begin{aligned} \text{Metabolisable energy} &= 0.82 \text{ DE} \\ &= 0.82 \text{ (0.19 DOMD \%) (see above)} \\ &= 0.16 \text{ DOMD} \end{aligned}$$

3.3.3 Sward and Animal measurments.

Daily herbage allowance, pregrazing herbage mass, residual herbage mass and degree of defoliation were used as defined by Hodgson (1979).

3.3.3.1 Intake.

Apparent herbage intake was calculated from the difference between the pregrazing herbage mass and the postgrazing herbage mass, multiplied by the area allocated daily and divided by the number of cows grazing during that time, that is;

$$\text{Herbage intake} = \frac{\text{HM (pre) - HM (post)}}{\text{cows/ha}}$$

Herbage intake was expressed as kgDM per cow per day for dry matter and as MJME per cow per day for ME intake. Substitution rate was defined as the change (unit) in intake of pasture when the animal consumed one unit of hay (Rogers, 1985). It was expressed in dry matter (kgDM) or ME (MJME).

3.3.3.2 Liveweight.

The cows were weighed on two consecutive days immediately prior to the start of the experiment and on two days commencing 48 hours after the termination of the experiment, to minimise the effect of possible gut fill. The liveweight change was defined as the difference in liveweight between the start and the end of the experiment.

3.3.3.3 Body condition.

Body condition score for each cow was assessed at the same time as the liveweight. The score system utilised was that reported by Scott *et al.* (1980), with a range of 1 - 10 (1 = very thin ; 10 = very fat).

3.3.3.4 Milk production and composition.

Individual morning and afternoon milk yields were recorded on two consecutive days each week except on the last week of the experiment where milk yield were recorded on 4 consecutive days. Aliquot milk sample were also taken at these times, for laboratory analysis of milk composition using Milkoscan analyses 140 A/B (Foss Electrict, Denmark).

3.4 Statistical analysis.

All data were analysed using the statistic analysis system (SAS) computing package (SAS, Institute, 1985).

Herbage mass residual herbage mass, herbage allowance, pasture DM intake and hay DM intake as well as liveweight and condition score were analysed using analysis of variance (Steel and Torrie, 1986).

The model used to define the above data were:

$$Y_{ij} = u + a_i + e_{ij}$$

where Y_{ij} = the observation on the j^{th} individual exposed to the i^{th} treatment, i = 1,2, j = 1,2 ...,8

u = the unknown population mean

a_i = the fixed effect of ith treatment, ie high and low digestibility hay.

e_{ij} = the random error associated with the j^{th} individual exposed to the i^{th} treatment. It is assumed that e_{ij} is normally distributed with mean 0 and variance σ^2.

Yield of milk, milk fat, protein and lactose and milk composition were analysed using the repeated measurement analysis of covariance (Finn, 1974) as the following model:

$$Y_{ijp} = u_p + \alpha_{ip} + \beta pX_{ij} + e_{ijp}$$

where Y_{ijp} = the observation on the j^{th} individual measured in the p^{th} week and belonging to the i^{th} treatment, i = 1,2, j = 1,2,...,8, p = 1,2,3,4

u_p = the overall mean for the week p.

α_{ip} = the effect of ith treatment in the p^{th} week.

β_p = regression coefficient of Yij on Xij in the p^{th} week.

X_{ij} = the pre-treatment observation on the j^{th} individual assign to treatment i.

e_{ij} = random residual effects which are assumed to be identically and independently distributed within the p^{th} week, but there are covariances for the same animal across weeks.

CHAPTER 4

RESULTS

4.1 Sward and Hay characteristics.

4.1.1 Pregrazing conditions

Mean values and results of ANOVA for the amount of pregrazing herbage mass (HM) for the two treatment are given in Table 4.1.

Table 4.1 Mean values and results of ANOVA for the pregrazing herbage mass (kgDM/ha) for the two treatment groups.

Paddock Number	low digestibility hay	high digestibility hay	SEM[1]	Level of significance
1	2207	2118		
2	1412	1382		
3	1628	1561		
4	1775	1775		
Mean	1775	1709	102	NS

1 : standard error of the mean

4.1.2 Feed intake.

The mean values for the amount of herbage, hay and total DM consumed by the two groups of cows are presented in Table 4.2. Herbage intake in high digestibility hay group was significantly ($P<0.05$) lower than low digestibility hay group while hay intake in high digestibility hay group was significantly ($P<0.0001$) greater than in low digestibility hay group. The herbage allowances were not significantly different between low digestibility hay and high digestibility hay groups as shown in table 4.2. The average stocking rate was 155 cows per hectare per the 12 hour period of grazing.

When the data were subjected to analysis separately within each individual paddock, the herbage intake in high digestibility hay group was not significantly lower than in low digestibility hay group (Table 4.3), due presumably to the fewer degrees of freedom. However the value for the high digestibility hay group was consistency lower than that for low digestibility hay group within each paddock.

Total DM intake was significantly (P<0.001) higher in high digestibility hay group than in low digestibility hay group. This was because of intake of the high digestibility hay DM eaten was significantly (P<0.0001) greater than the low digestibility hay DM eaten and despite the smaller pasture intake in the high digestibility hay group.

Table 4.2 Mean values and results of ANOVA for herbage allowance, the amount of DM intake from the pasture, hay and total apparent DM intake (kgDM/cow/day) for the two treatment groups.

	low digestibility hay	high digestibility hay	SEM	level of significance
Herbage allowance	11.0	10.7	0.4	NS
Apparent DM intake				
as pasture	4.30	3.85	0.15	*
as hay	6.53	8.65	0.29	***
Total DM intake	10.85	12.50	0.37	**

SEM : standard error of the mean
* : significance at P<0.05
** : significance at P<0.01
** : significance at P<0.0001

Table 4.3 Mean values and results of ANOVA for the amount of pasture intake (kgDM/cow/day) for the two treatments when the data was separately analysed in individual paddocks.

		Pasture intake			
		low digestibility hay	high digestibility hay	SEM	level of significance
Paddock Number	days grazed				
1	7	4.35	3.91	0.40	NS
25	3.70	3.50	0.40	NS	
36	4.77	3.78	0.47	NS	
42	5.33	3.80	---	--	

SEM : standard error of the mean

4.1.3 Chemical analysis and gross energy determination of the feeds.

The DMD of the high quality hay was higher than that of the low quality hay. The *in vivo* and *in vitro* methods gave almost identical values for DMD of the high quality hay, whereas for the low quality hay, the *in vivo* value was 2.1% units lower than the *in vitro* value.

Table 4.4 Data for the analysis of feeds used in the experiments.

FEED	*in vivo* %DMD	-------*in vitro*----- %DMD	%DOM	%DOMD	%CP	%Ash	GE --MJ/kgDM--	ME
		67.5-74.1	72.6-80.5	62.2-70.3	17.7-18.7	11.5-14.0	17.7-18.7	10.80-11.8
Low quality hay	52.0	54.0	49.1	53.3	6.9	7.9	17.5	7.9
High quality hay	57.3	57.7	51.9	57.7	17.7	10.0	18.0	8.3

4.1.3.1 Metabolisable energy intake.

The calculated mean values for the quantities of ME intake from the herbage, hay and total ME intake (MJ per cow per day) by the two different groups are shown in Table 4.4.

Due to the smaller DM intake in herbage, the ME consumption as pasture was significantly ($P<0.05$) lower in the high digestibility hay group than in the low digestibility hay group. The difference in ME intake between low digestibility hay and high digestibility hay group was approximately 4 MJ per cow per day.

The ME intake as hay was significantly higher ($P<0.0001$), by approximately 20 MJ per cow per day in the high digestibility hay group. Total ME intake was significantly ($P<0.001$) higher in the high digestibility hay group than in the low digestibility hay group. The apparent total ME intake was increased by approximately 16 MJ per cow per day for the high digestibility hay group.

Table 4.5 Means values and results of ANOVA for the quantities of ME intake from the pasture, hay and total ME intake (MJ/cow/day) for the two treatment groups.

	low digestibility hay	high digestibility hay	SEM	level of significance
ME intake				
as pasture	48.1	44.2	1.7	*
as hay	51.0	71.2	2.4	***
Total ME intake	99.1	115.4	2.8	***

SEM : standard error of the mean
* : significance at P<0.05
*** : significance at P<0.001

4.1.4 Residual herbage mass.

Mean values for individual paddocks and mean values for residual herbage mass (RHM) are shown in Table 4.6. The quantities of RHM in low digestibility hay group were consistently smaller than those for the high digestibility hay group, but the difference was not significant.

The mean values for degree of defoliation are also shown in Table 4.6. The degree of defoliation was slightly higher (NS) in the low digestibility hay group than in the high digestibility hay group. The degree of defoliation was increased by 3 percent when low digestibility hay was supplemented compared with when high digestibility hay supplemented.

Table 4.6 Mean values and results of ANOVA for residual herbage mass (RHM, kgDM/ha) for the two treatment groups.

	low digestibility hay	high digestibility hay	SEM	level of significance
Paddock Number				
1	1507	1520	227	NS
2	938	972	119	NS
3	826	1000	68	NS
4	960	1230	-	-
mean	1101	1129	65	NS
Degree of defoliation (%)	40.3	37.3	1.8	NS

SEM : standard error of the mean

4.2 Animal Performance.

4.2.1 General.

The data for the cows at the start of the experiment are given in the previous chapter (see Table 3.1). The results reported in the following tables were adjusted using the initial statistics as covariates. Initial yield of milk, milk fat, milk protein and milk lactose were used as covariates in the statistical analysis of subsequent yields of milk, milk fat, milk protein and milk lactose respectively. Concentrations of fat, protein and lactose were also analysed using their initial concentrations as covariates.

4.2.2 Yields of milk, milk fat, milk protein and milk lactose.

The daily yields of milk, milk fat milk protein and milk lactose of the two treatments are shown in Tables 4.7 a-d.

The cows supplemented by high digestibility hay produced larger yields than the cows supplemented by low quality hay but the differences were not significant over the whole period. In the first week of the experiment the cows in the high digestibility hay group produced significantly ($P<0.01$) more milk than the cows in the low digestibility hay group, however the size of the difference declined with the progress of the experiment as shown in Table 4.7a.

There was no significant effect of the time on milk yield nor an interaction between time and treatment effect (Table 4.7a). This suggests that the small difference between treatments was constant with time.

Milk fat yields are shown in Table 4.7b. Cows supplemented by high digestibility hay produced slightly larger yields but the differences were not significant. However, the significant effect of time was observed, because yields of milk fat decreased as time progressed.

Yield of protein and lactose are shown in Table 4.7c and 4.7d respectively. No significant differences in protein and lactose yield between treatments were observed.

Milk yield in the period after treatments had finished.

No differences in yields of milk, milk fat, protein and lactose were observed in week one following the termination of the experimented treatment.

Table 4.7a Yield of milk (kg/cow/day) for the two treatment groups, during the experiment.

	low[a] digestibility hay	high[a] digestibility hay	SEM	Level of significance Trt	Time	Trt*Time
Pre-exp[1].	19.8	20.0	0.49	NS		
Experimental period						
Week 1	15.4	17.2	0.35	**		
Week 2	15.0	16.1	0.59	NS		
Week 3	14.3	15.4	0.56	NS	NS	NS
Week 4	14.2	15.2	0.52	NS		
After experiment						
Week 1	17.1	17.3	1.13	NS		

SEM : standard error of the mean
1 : Pre-experimental period.
a : adjusted values using initial corresponding yields as covariates

Table 4.7b Yield of milk fat (kg/cow/day) for the two treatment groups, during the experiment.

	low[a] digestibility hay	high[a] digestibility hay	SEM	Level of significance Trt	Time	Trt*Time
Pre-exp[1].	0.99	1.00	0.04	NS		
Experimental period.						
Week 1	0.72	0.73	0.02	NS		
Week 2	0.65	0.72	0.02	NS		
Week 3	0.63	0.64	0.02	NS	*	NS
Week 4	0.61	0.66	0.02	NS		
After experiment						
Week 1	0.73	0.75	0.04	NS		

SEM : standard error of the mean
1 : Pre-experimental period
a : adjusted values using initial corresponding yields as covariates

Table 4.7c Yield of protein (kg/cow/day) for the two treatment groups, during the experiment.

	low[a] digestibility hay	high[a] digestibility hay	SEM	Level of significance Trt	Time	Trt*Time
Pre-exp[1].	0.74	0.72	0.02	NS		
Experimental period						
Week 1	0.54	0.56	0.02	NS		
Week 2	0.45	0.49	0.02	NS		
Week 3	0.45	0.49	0.01	NS	NS	NS
Week 4	0.45	0.50	0.01	NS		
After experiment						
Week 1	0.59	0.59	0.03	NS		

SEM : standard error of the mean
1 : Pre-experimental period.
a : adjusted values using initial corresponding yields as covariates

Table 4.7d Yield of lactose (kg/cow/day) for the two treatment groups, during the experiment.

	low[a] digestibility hay	high[a] digestibility hay	SEM	Level of significance Trt	Time	Trt*Time
Pre-exp[1].	0.99	0.99	0.02	NS		
Experimental period						
Week 1	0.83	0.87	0.03	NS		
Week 2	0.76	0.82	0.02	NS		
Week 3	0.71	0.78	0.02	NS	NS	NS
Week 4	0.71	0.77	0.02	NS		
After experiment						
Week 1	0.84	0.86	0.05	NS		

SEM : standard error of the mean
1 : Pre-experimental period
a : adjusted values using initial corresponding yields as covariates

4.2.3 Milk composition.

Tables 4.8 a-c shows the concentrations of milk fat, milk protein and milk lactose for the two treatments.

The concentration of milk fat for the two treatments are shown in Table 4.8a. In the first week of the experiment milk fat concentration was significantly ($P<0.05$) higher in the low digestibility hay group than in the high digestibility hay group. However, The concentration of milk protein and milk lactose are shown in tables 4.8b and 4.8c respectively. There were no significant differences between treatments in protein and lactose percentage, despite a slightly higher in the concentration of both protein and lactose were observed in the low digestibility hay group than in the high digestibility hay group throughout the experiment. A significant effect of an interaction between time and treatment was observed for the lactose concentration.

No residual effect on milk fat milk protein and milk lactose was observed a week after the termination of the experiment.

Table 4.8a The concentration of fat (%) for the two treatment groups, during the experiment.

	low[a] digestibility hay	high[a] digestibility hay	SEM	Level of significance Trt	Time	Trt*Time
Pre-exp[1].	5.24	5.14	0.22	NS		
Experimental period						
Week 1	4.83	4.42	0.19	*		
Week 2	4.68	4.50	0.16	NS		
Week 3	4.65	4.28	0.20	NS	NS	NS
Week 4	4.52	4.41	0.21	NS		
After experiment						
Week 1	4.45	4.28	0.18	NS		

SEM : standard error of the mean
1 : Pre-experimental period
a : adjusted values using initial corresponding yields as covariates.

Table 4.8b The concentration of protein (%) for the two treatment group, during the experiment.

	low[a] digestibility hay	high[a] digestibility hay	SEM	Level of significance Trt	Time	Trt*Time
Pre-exp[1].	3.80	3.63	0.19	NS		
Experimental period						
Week 1	3.59	3.32	0.16	NS		
Week 2	3.02	2.98	0.09	NS		
Week 3	3.13	3.08	0.05	NS	NS	NS
Week 4	3.24	3.18	0.09	NS		
After experiment						
Week 1	3.45	3.39	0.12	NS		

SEM : standard error of the mean
1 : Pre-experimental period.
a : djusted values using initial corresponding yields as covariates

Table 4.8c The concentration of lactose (%) for the two treatment groups during the experiment.

	low[a] digestibility hay	high[a] digestibility hay	SEM	Level of significance Trt	Time	Trt*Time
Pre-exp[1].	4.99	5.08	0.05	NS		
Experimental period						
Week 1	5.35	5.24	0.0	NS		
Week 2	5.11	4.94	0.08	NS		
Week 3	4.92	4.93	0.07	NS	NS	*
Week 4	4.95	4.95	0.06	NS		
After experiment						
Week 1	5.00	4.86	0.08	NS		

SEM : standard error of the mean
1 : Pre-experimental period.
a : adjusted values using initial corresponding yields as covariates

4.2.4 Liveweight and condition score.

The mean values for the initial liveweight, the final liveweight adjusted for initial liveweight, liveweight change, the initial score, the final score and change in condition score are given in Table 4.9.

Both the low digestibility hay group and the high digestibility hay group cows gained weight and the gain in liveweight of the high digestibility hay group was significantly ($P<0.05$) higher than in the low digestibility group.

Body condition increased in both groups, but the increases in body condition was larger in the high digestibility hay group ($P<0.01$). It should be noted that the initial condition score was significantly ($P<0.05$) higher in the low digestibility hay group. At the termination of the experiment, the condition scores in the low digestibility hay group were still slightly higher than in the high digestibility hay group but the differences between both groups were not significant.

Table 4.9 Mean values and results of ANOVA for the initial and final liveweight (kg/cow), the initial and final body condition score (units), liveweight change (gm/day) and condition score change (unit/month) for the two treatment groups.

	low[a] digestibility hay	high[a] digestibility hay	SEM	level of significance
Initial LW (kg)	404	408	18.4	NS
Final LW[a] (kg)	415	424	3.6	*
LW change (gm/day)	298	623	120.2	*
Initial CS	4.34	3.78	0.2	*
Final CS	4.55	4.22	0.2	NS
CS change (unit/month)	0.21	0.44	0.1	**

SEM : standard error of the mean.
a : adjusted using initial weight or condition score as covariates

Figure 4.1 Effect of hay digestibility on total DM intake

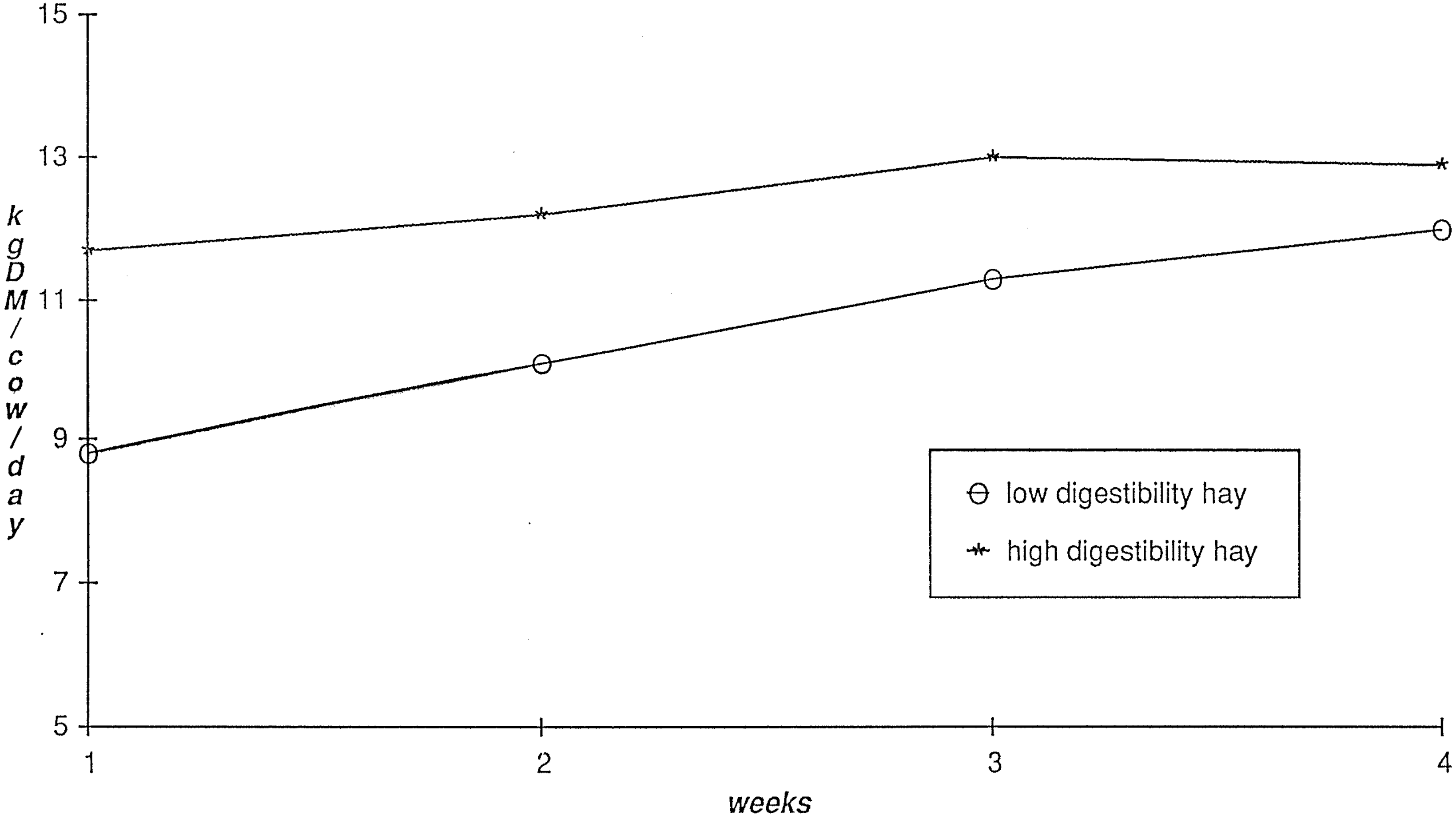


Figure 4.2 Effect of hay digestibility on total ME intake

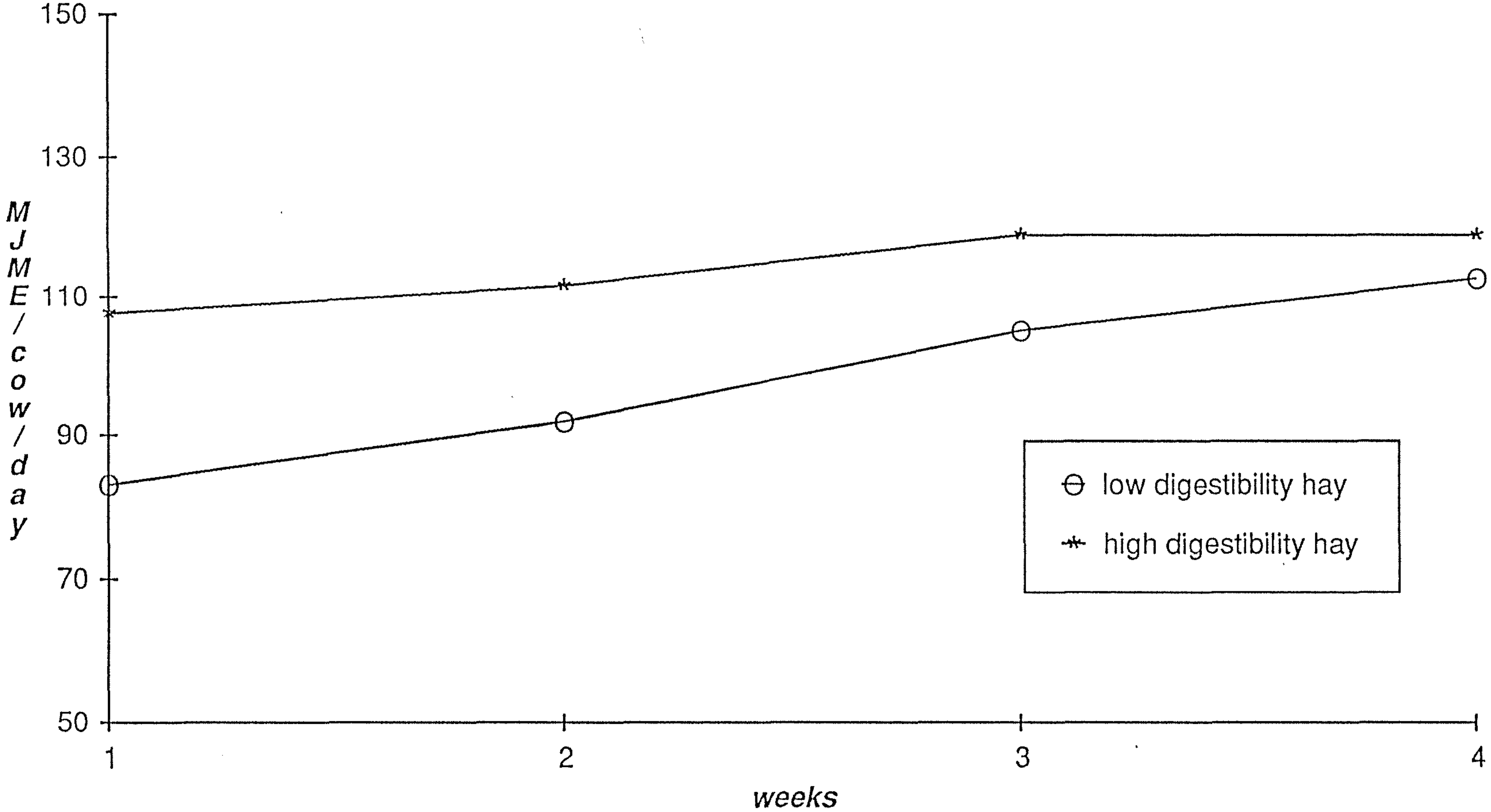


Figure 4.3 Effect of hay digestibility on milk yield

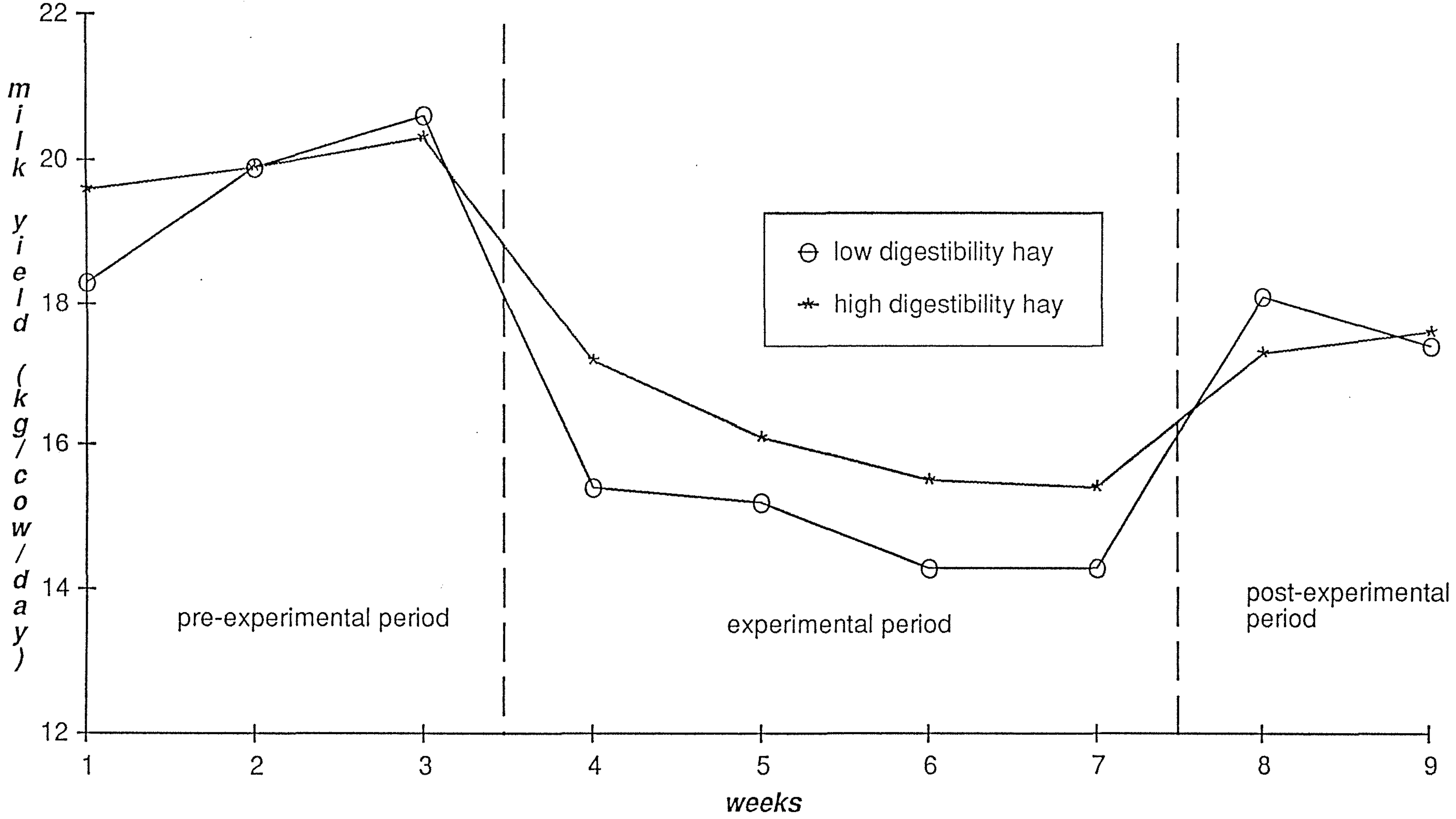


Figure 4.4 Effect of hay digestibility on milk fat yield

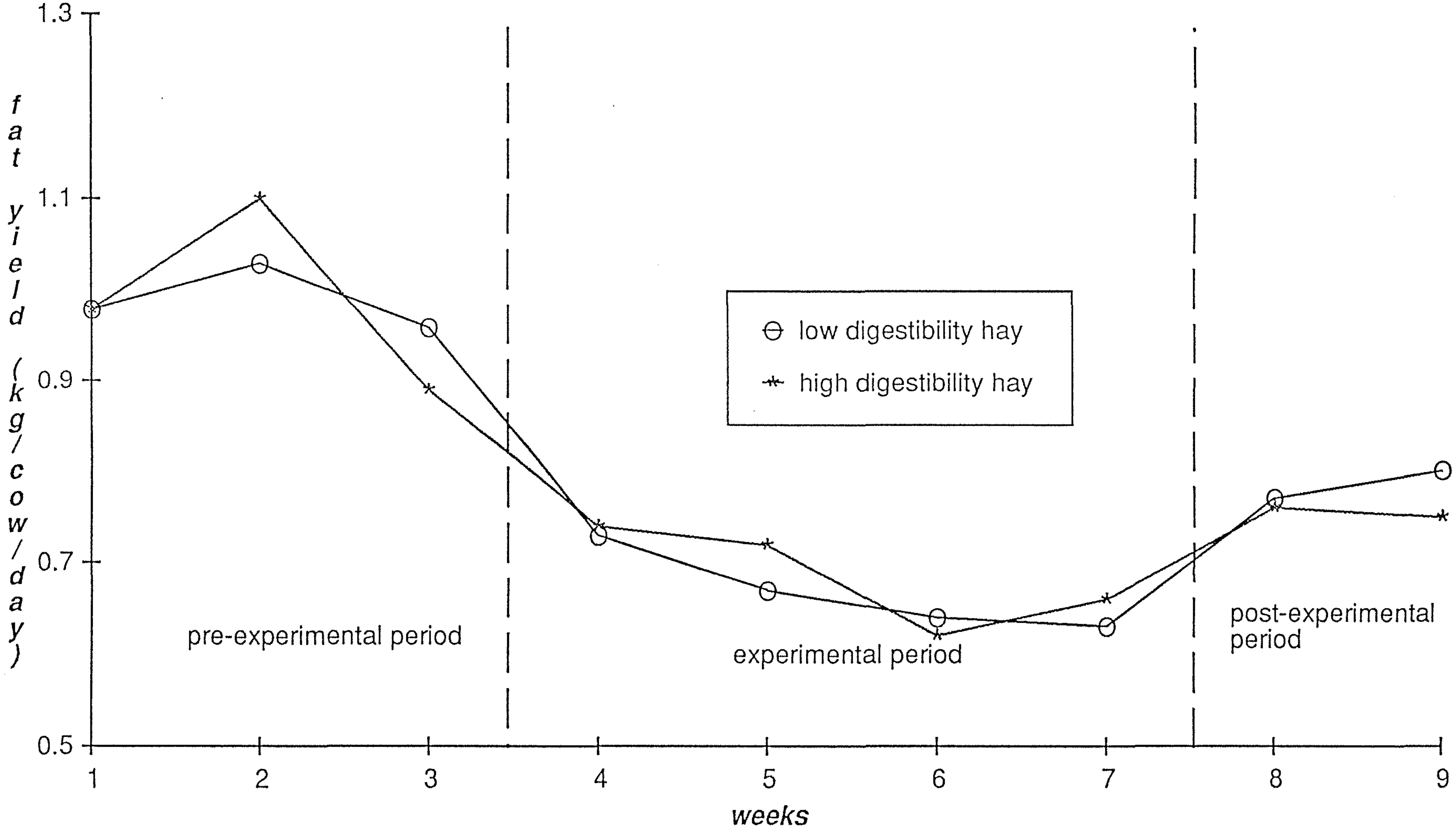


Figure 4.5 Effect of hay digestibility on protein yield

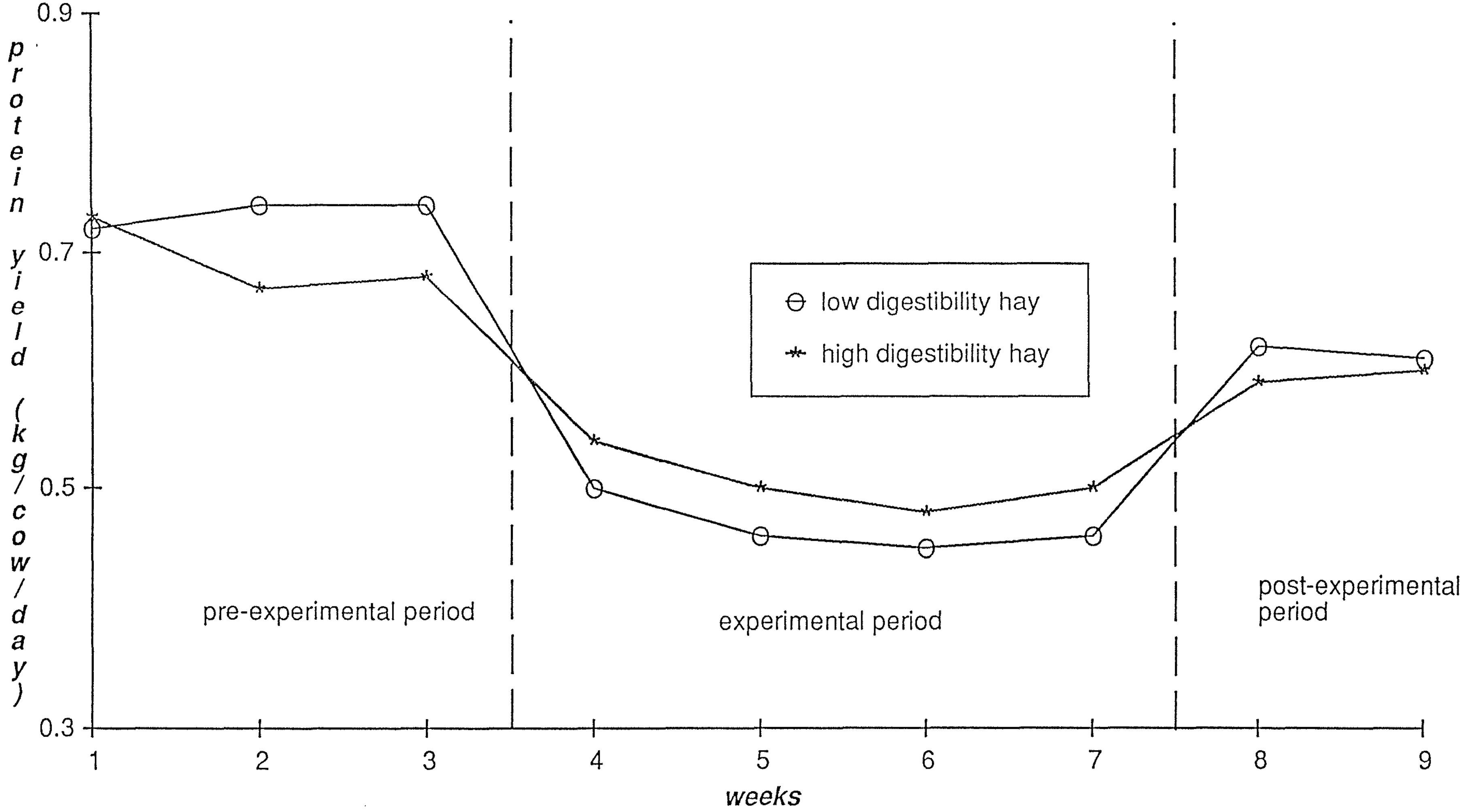


Figure 4.6 Effect of hay digestibility on lactose yield

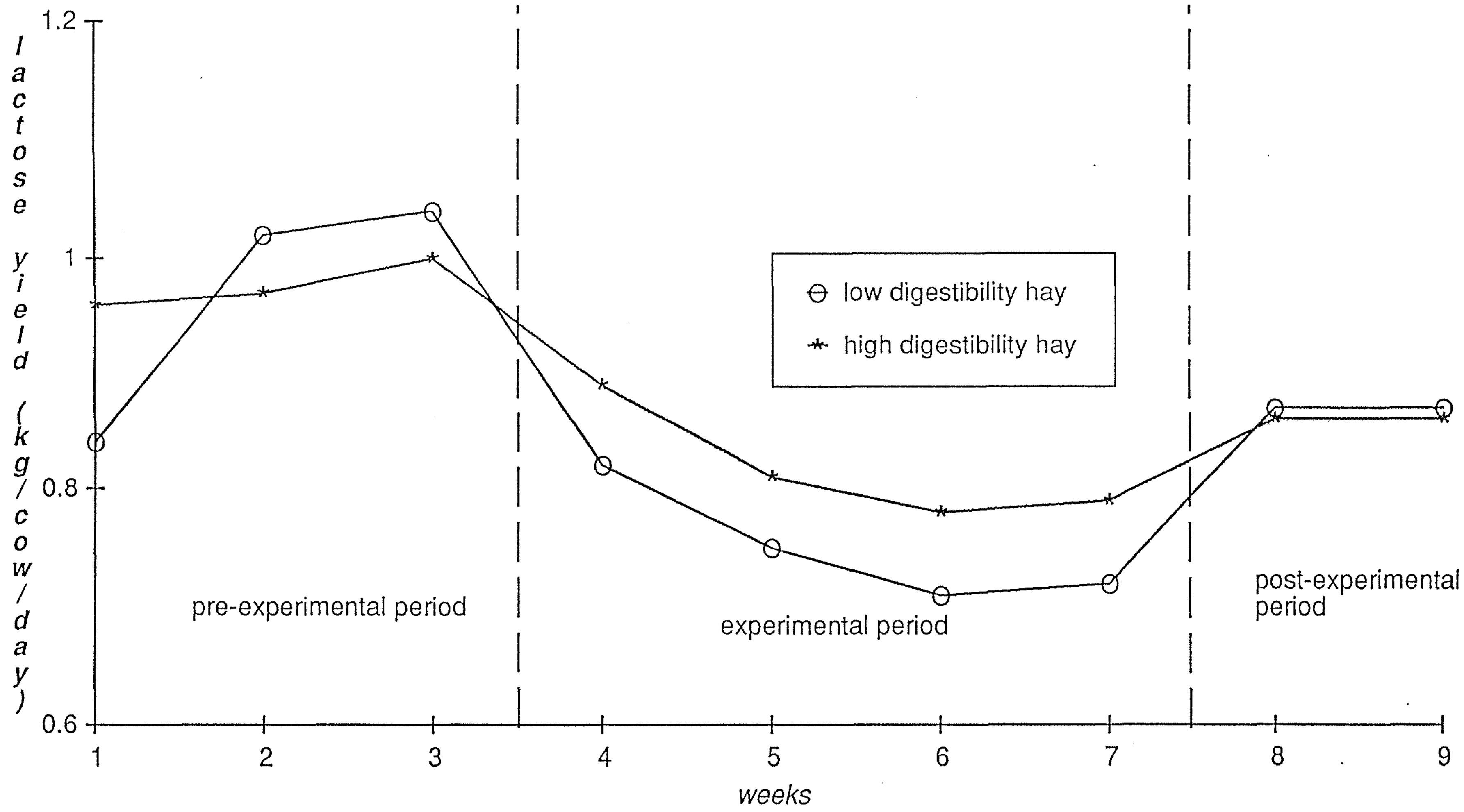


Figure 4.7 Effect of hay digestibility on milk fat concentration

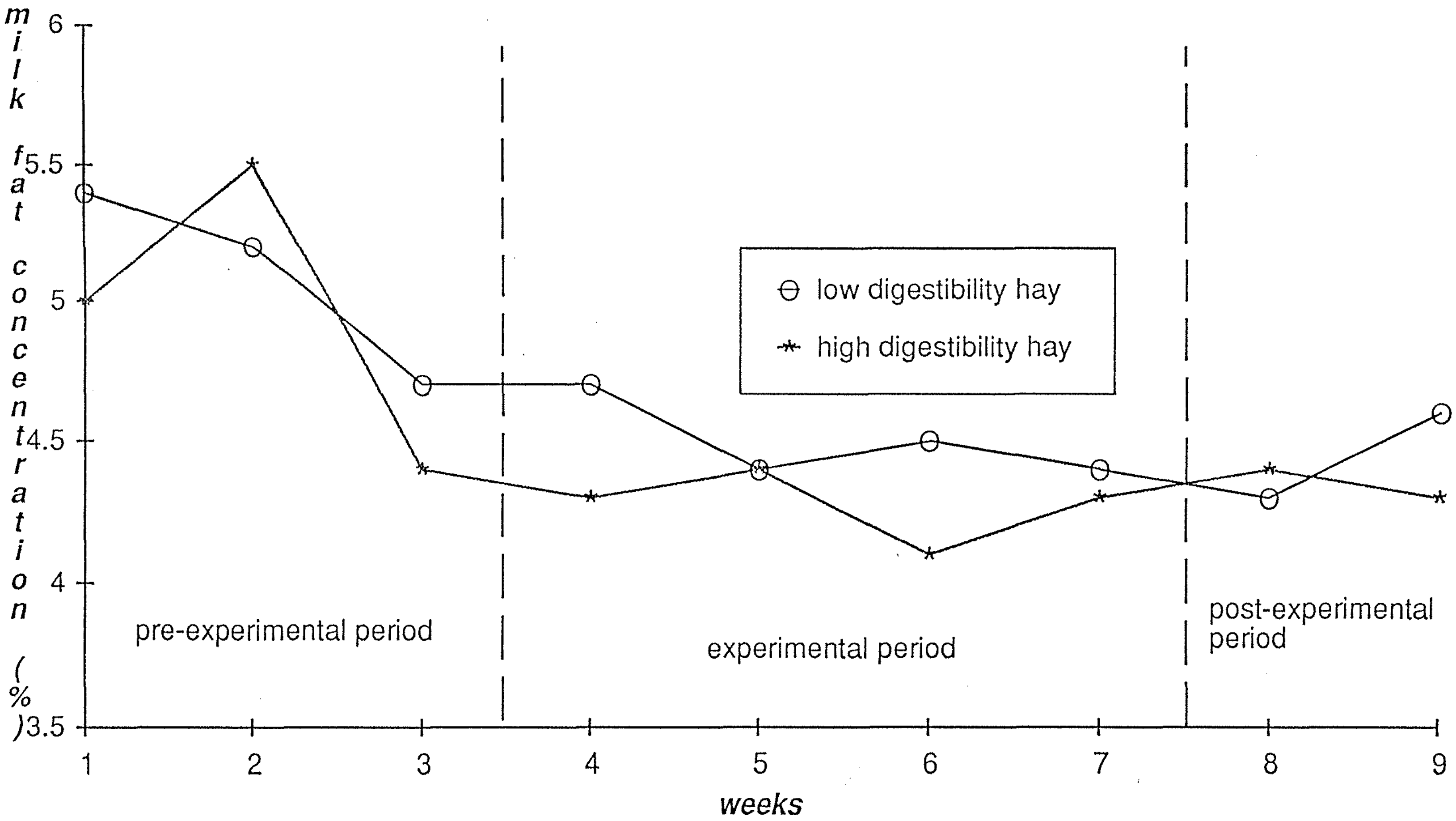


Figure 4.8 Effect of hay digestibility on protein concentration

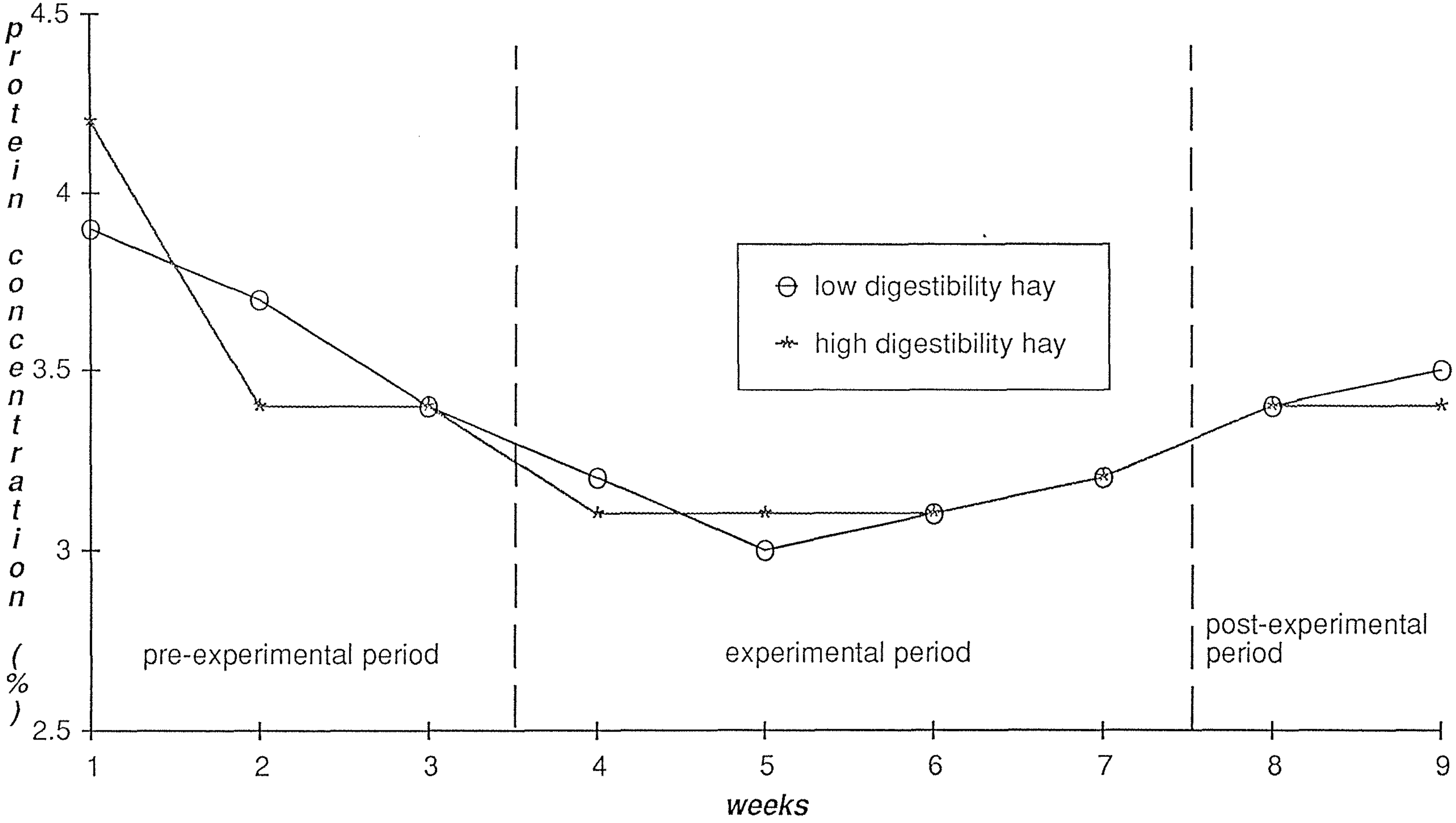
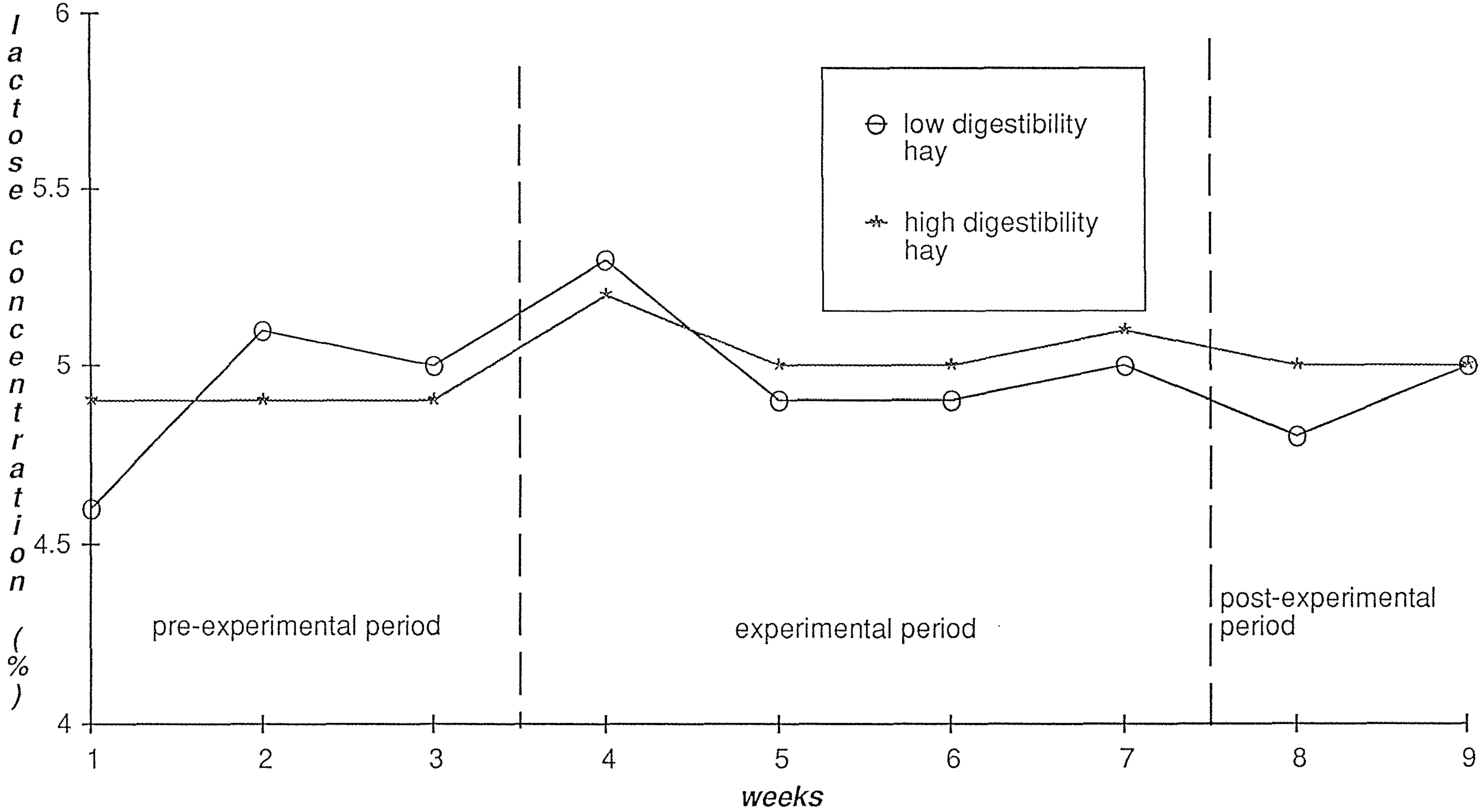


Figure 4.9 Effect of hay digestibility on lactose concentration



CHAPTER 5

DISCUSSION

5.1 Effects of hay quality on intake.

5.1.1 Pre-grazing herbage mass.

The average herbage mass offered in this experiment was 1775 and 1709 kgDM per hectare in the low digestibility hay group and the high digestibility hay group, respectively as shown in Table 4.1. These values are slightly lower than the range of values within which it was suggested that DM intake is not affected by herbage mass (2000-4000 kgDM per hectare) (Combellas and Hodgson, 1979; Meijs, 1981; Holmes, 1987). In this experiment, herbage mass was measured by the sward cutting technique. The pastures were cut by the same person during the whole experiment to try to avoid change in determination (Thomson, 1986).

5.1.2 Herbage allowance.

The herbage allowance offered to the cows was on average 11.0 and 10.7 kgDM per cow per period of 12 hours grazing in the low digestibility hay group and the high digestibility hay group, respectively as shown in Table 4.2. Herbage DM allowances presented in this experiment, therefore, would have been equivalent to about 22 kgDM per cow per 24 hour day, which are below the level generally associated with maximum intake (Holmes, 1987). This indicates the degree of restriction in herbage intake.

5.1.3 Digestibility of the feeds.

The *in vitro* digestibility of pasture grazed in this experiments were in the range of 67.5 - 76.4% with the ME concentration of 10.80 - 11.80 MJME per kgDM. These are the average values for spring pasture suggested by Holmes and Wilson (1984).

The *in vivo* digestibility of low and high quality hay were 52.0 and 57.3% respectively, whereas the value obtained from *in vitro* digestibility was 53.3 and 57.7%. The value for high digestibility hay is nearly identical in both *in vitro* and *in vivo* digestibility. However, for low digestibility hay , the *in vitro* digestibility was about 1.4% higher than *in vivo* digestibility, this difference was probably due to the residual standard deviation for the *in vivo* prediction from *in vitro* digestibilities (Roughan and Holland, 1977; Le Du and Penning, 1982).

In the calculation of the quantities of ME offered and consumed, it was assumed that the digestibilities of individual dietary components were not affected by the types of feed eaten, based on the suggestion of Aerts *et al.* (1986) which indicated that associative digestibility effects between feeds in a ration are neglible for most rations. It was also assumed that the level of supplementation did not affect the digestibility of pasture consumed, based on the suggestion of Eldridge and Kat (1980a) that for grazing cows supplemented with hay, hay feeding would not affect digestibilities of the herbage selected by the animals.

5.1.4 Effects of hay digestibility on intake and pasture sparing effects.

There is little information about the effect of the digestibility of conserved forage supplemented to grazing dairy cows on pasture DM intake and pasture sparing effects. Most of the data about the effect of the quality of conserved forage on DM intake discussed in this chapter were obtained from stall fed dairy cows given silage of different digestibilities as the basal feed and supplemented by different levels of concentrates.

5.1.4.1 Hay intake.

It was accepted, in general, that the DM intake of conserved forage increases with increasing digestibility (Blaxter and Wilson, 1963; Castle and Watson 1969, 1970, 1971; Castle *et al.* 1980; Gordon, 1980ab; Moisey and Leaver, 1984; Rogers and Robinson, 1984; Phipps *et al.* 1987). In the present experiment, the intake of high digestibility hay was significantly ($P<0.0001$) greater than intake of low digestibility hay (Table 4.2). Similar results were reported in experiments where hay was fed as the basal feed and supplemented with concentrates (Blaxter and Wilson, 1963; Llamas *et al.* 1987; Astibia *et al.* 1987). The possible explanation is that high digestibility hay may contain more soluble DM and have a faster rate of digestion (Llamas *et al.* 1987) and may also give a shorter retention time in the rumen (Astibia *et al.* 1987). These factors would contribute to the faster passage of the high digestibility hay and result in high intake (Llamas *et al.* 1987). When silage was fed as the basal feed and supplemented with concentrates, it was found in many experiments that silage DM intake was greater for high digestibility silage than low digestibility silage as shown in Table 5.1.

Table 5.1 The intake of conserved forage of different digestibilities, from published data and the present experiments.

Detail	Digestibility of forage Low	High	Diff bet. trt.	SEM	level of significance
HAY					
The present experiment					
DMD (%)	52.0	57.3	5.4		
Intake hay (kg)	6.5	8.7	2.2	0.29	***
pasture (kg)	4.3	3.9			
SILAGE					
Castle and Watson (1969)					
DMD (%)	67.0	74.0	7.0		
Intake silage(kg)	6.1	6.9	0.8	0.28	*
conc. (kg)	5.2	5.2			
Castle and Watson (1970)					
DMD(%)	62.9	65.5	2.6		
Intake silage (kg)	7.3	7.5	0.2	0.22	NS
conc. (kg)	5.0	5.0			
Castle and Watson (1971)					
DMD(%)	60.9	68.7	7.8		
Intake silage (kg)	7.6	7.9	0.3	0.22	*
conc. (kg)	5.1	5.1			
DMD(%)	62.2	71.9	9.7		
Intake silage (kg)	6.7	7.2	0.5	0.22	**
conc. (kg)	5.0	5.0			
Taylor and Aston (1976) (Early lactation.)					
DMD (%)	66.3	71.1	4.8		
Intake silage (kg)	6.5	5.6	-.9	0.32	*
dried grass (kg)	9.7	9.7			
DMD (%)	64.7	70.7	6.0		
Intake silage (kg)	7.5	6.8	-.7	0.32	*
dried grass (kg)	6.4	6.4			

(Mid Lactation.)					
DMD (%)	66.3	61.1	4.8		
Intake silage (kg)	8.5	7.7	-.8	0.27	NS
dried grass (kg)	6.0	6.0			
DMD (%)	64.7	70.7	6.0		
Intake silage (kg)	8.8	8.5	-.3	0.27	NS
dried grass (kg)	4.0	4.0			
Gordon and Murdoch (1978)					
DMD (%)	70.0	72.9	2.9		
Intake silage (kg)	9.8	11.9	2.1	0.33	**
conc. (kg)	3.8	3.8			
Castle *et al.* (1980)					
DMD (%)	62.4	65.0	2.6		
Intake silage (kg)	9.4	10.1	0.7		*
conc. (kg)	3.6	3.5			
Gordon (1980a)					
DMD (%)	62.4	70.0	7.6		
Intake Silage (kg)	8.2	9.4	1.2	0.27	*
conc. (kg)	8.8	8.8			
Gordon (1980b)					
DMD (%)	61.7	72.6	10.9		
Intake silage (kg)	8.1	10.7	2.6		
conc. (kg)	7.6	7.6			
Moisey and Leaver (1984)					
DMD (%)	61.5	66.4	4.9		
Intake silage (kg)	10.3	11.5	1.2	0.39	*
conc. (kg)	4.4	4.4			
Rogers and Robinson (1984)					
DMD (%)	71.6	73.5	1.9		
Intake silage (kg)	10.7	11.4	0.7	0.79	*
pasture (kg)	3.5	3.8			
DMD (%)		66.1	69.2	3.1	
Intake silage (kg)	10.6	11.3	0.7	0.79	*
pasture (kg)	3.5	3.8			
Phipps *et al.* (1987)					
DMD (%)	60.0	68.0	8.0		
Intake silage (kg)	6.2	7.5	1.3	0.3	*
conc. (kg)	4.3	4.3			

SEM : standard error of the mean
* : significance at P<0.05
** : significance at P<0.01
*** : significance at P<0.0001

The data from these published experiments show that intake of silage DM was increased, on average, by 0.15 kg per unit rise in digestibility. However it has to be mentioned that these responses were derived for forage given in combination with concentrates, thus, the effect of digestibility on forage intake may well be reduced (Thomas, 1980). This is because of the higher substitution rate which was observed in cows fed on high digestibility conserved forage compared with low digestibility conserved forage when concentrate was supplemented (Blaxter and Wilson, 1963; Thomas, 1980). This evidence is probably due to the effects of concentrate in improving the rumen fermentation in cows fed on low quality roughage. When silage was fed as the sole feed, the value of 0.25 kg per unit rise in digestibility was observed (Ostergaard, 1979 cited by Thomas, 1980). The data in Table 5.1 shows that the range in response varied from -0.12 (Taylor and Aston, 1976) to +0.72 (Gordon and Murdoch, 1978) kgDM per unit rise in digestibility. This variation may in part be the result of differences in fermentation between silages. In the experiments carried out by Taylor and Aston (1976), it was postulated that the decrease of intake in response to the increase in silage digestibility was probably due to the lower DM content and significantly higher acidity (particularly a high lactic acid content) of the high digestibility silage, when compared with the low digestibility silage. The present experiment appears to be the only case where hay of different digestibilities were supplemented to cows grazing on pasture. Therefore, it is difficult to compare the present response of the increase in intake of 0.40 kgDM hay per unit rise in digestibility directly with the published experiments, shown in Table 5.1. However, the response in an increase in intake obtained from the present experiment is similar to the increase in intake of 0.38 kg silage per unit rise in digestibility when silage was fed together with cut pasture (Rogers and Robinson, 1984). In the present study, the increase in intake due to the increase in hay digestibility could be explained by the higher proportion of leaves in high digestibility hay compared with low digestibility hay. In addition, it may also due to the fact that the high digestibility hay appeared to be more attractive (colour and smell) than the low digestibility hay in the present experiment.

5.1.4.2 Effects on pasture intake.

The present study has shown that cows fed on high digestibility hay consumed significantly($P<0.05$) less pasture than cow fed on low digestibility hay. This was probably due to the greater intake of high digestibility hay. Thus, the reduction in pasture intake in the high digestibility hay group was probably due to the limitation of space in the alimentary tract.

Similar results have been reported when high energy supplements such as concentrates were fed to dairy cows grazed on pasture. Meijs (1986) found that pasture intake decreased as the digestibility of concentrate increased. However, the reduction in pasture intake observed may come from different causes. Since the decrease in pasture intake when high energy concentrate was supplemented may be due to the reduction in rumen pH when this easily fermented substance (high energy concentrate) was fed. This results in lowering the rate of breakdown of fibrous particles in the recticulorumen and consequently restricting intake of new feed, as discussed in section 2.3.1.3. Also the increase in nutrients absorbed when high energy concentrates were supplemented may cause the operation of chemostatic mechanisms.

5.1.4.3 Effects on residual herbage mass.

Residual herbage mass was slightly higher when high digestibility rather than low digestibility hay was fed but the differences were not statistically significant (Table 4.6). Since residual herbage mass is the consequence of the difference between pregrazing herbage mass and herbage intake, thus, an increase in residual herbage mass was likely to be caused by the decrease in herbage intake by cows supplemented by high digestibility hay.

The size of the change in residual herbage mass depends largely on the change in herbage intake per cow (kgDM per cow) and stocking rate (cows per hectare). The change in the herbage intake per cows is determined by the intake of supplements and the substitution rate. The differences in residual herbage mass of the two different groups in the present study is presumably due mainly to the difference in herbage intake per cow.

Supplementation with high digestibility hay caused a pasture sparing effects, and the spared pasture could be utilised at a later grazing. Cows supplemented with high digestibility hay left about 28 kgDM residual herbage mass per hectare more than cows supplemented with low digestibility hay. The amount of extra residual herbage mass left due to the high digestibility hay supplementation represented an average

330 MJME per hectare. If all residual herbage mass left was subsequently utilised, approximately 66 kg of milk could be produced from that amount of extra residual herbage mass. However, such residual herbage mass may not be utilised and the pasture may become aged and be of low quality or decay and disappear.

The extra residual herbage mass increased by the supplementation of high digestibility hay could increase the amount of pasture growth in the subsequent period due to the higher leaf area index (Brougham, 1970; Mathews and Gray, 1979; Stockdale *et al.* 1981; Hoogendorn, 1987). It was reported that pasture growth rate can increase by 20 kgDM per hectare per day for each increase of 100 kgDM per hectare in residual pasture (Santamaria and McGowan, 1982) when pasture residual is less than 2200 kgDM per hectare (Mathews and Gray, 1979). In the present experiment, pasture residual is about 1100 kgDM per hectare, thus, the increase in residual pasture mass would probably cause an increase in the subsequent pasture growth and a positive carry over effect on animal production could be expected. Alternately, a very high residual pasture would result in sward having a greater percentage of reproductive tillers during late spring, and thus a greater percentage of stem and consequently a greater percentage of fibrous material, all of which would reduce the quality of pasture. (Rogers, 1985; Hoogendorn, 1987). The recommended level of residual pasture which not only gives a reasonable net herbage accumulation rate but also gives a leafy, high quality pasture in spring and subsequent period, notably early summer, is approximately 1600 kgDM per hectare (Hoogendorn, 1987) while 2200 kgDM per hectare has been suggested by Thomson (1986) and Mathews and Gray (1979), but this value appears to be too high, by comparison of the present data and other published data (Holmes, 1987).

The decrease in pasture intake caused by use of high digestibility hay also caused a small decrease in the degree of defoliation (37% in high digestibility hay group and 40% in low digestibility hay group). The reason for this and the possible consequences have been discussed above.

5.2 Effects of hay digestibility on milk production and composition.

5.2.1 Milk yield.

The prime objective of the present study was to determine the effect of the digestibility of hay supplementation to dairy cows grazing on pasture during early lactation. Most of the previous experiments have always reported an increase in milk yield with hay supplementation in cows grazed on restricted pasture (Parker, 1966; Stockdale *et al.* 1981; Stockdale and King 1982; Rogers *et al.* 1983; Rearte *et al.* 1986). However, the effect of hay digestibility on animal performance has rarely been investigated.

Milk production was significantly ($P<0.05$) greater in cows supplemented by high digestibility rather than low digestibility hay, during the first week of experiment. However this difference in milk yield between the two treatment groups declined in the successive weeks of the experiment. So that although the difference remained, it was not significant in week 2, 3, 4 of the experiment (Table 4.7a). (The differences in milk yield between two groups were 1.8 kg milk per cow per day in first week and declined to 1.2, 1.1 and 1.0 kg milk per cow per day in week 2, 3 and 4 of the experiment respectively.) The possible explanation is that the cows in low digestibility hay group were able to partially compensate for the low ME content of hay intake by consuming significantly more pasture ($P<0.05$) than cows supplemented with high digestibility hay. It was found, in addition, that the differences in pasture intake between the two treatment groups increased in successive weeks of the experiment (Table 4.3). Therefore the differences in ME intake per cow per day between the two treatment groups declined with the successive week of the experiment (24.4, 19.5, 13.7, 6.3 MJME in week 1, 2, 3, 4 respectively). This may lead to the smaller differences in milk yield as the experiment progressed because of the reduction in the differences of ME intake between the two treatment groups and the higher efficiency with which pasture is converted into milk compared to hay (Stockdale *et al.* 1981). Moreover, the initial condition score of cows in the high digestibility hay group was lower than those in the low digestibility hay group (Table 4.9), thus during the time of underfeeding cows in the low digestibility hay group may mobilise more body reserves for milk production. This may contribute to the smaller differences, than expected, in milk yield between the two treatment groups.

Published information about the effect of hay digestibility on milk yield is lacking. However, the effect of silage digestibility on milk yield had been studied in many experiments and these are summarised in Table 5.2.

Table 5.2 Effects of the digestibility of conserved forage on milk yield, from published data and the present experiments.

Detail	Digestibility of forage Low	High	Diff bet. trt.	SEM	level of significance
HAY					
The present experiment					
DMD (%)	52.0	57.3	5.4		
Intake hay (kg)	6.5	8.7	2.2	0.29	***
pasture (kg)	4.3	3.9			
Milk yield Week 1	15.4	17.2	1.8	0.35	**
Week 2	15.0	16.2	1.2	0.59	NS
Week 3	14.3	15.4	1.1	0.56	NS
Week 4	14.2	15.2	1.0	0.52	NS
SILAGE					
Castle and Watson (1969)					
DMD (%)	67.0	74.0	7.0		
Intake silage(kg)	6.1	6.9	0.8	0.28	*
conc. (kg)	5.2	5.2			
Milk Yield (kg)	14.5	15.6	1.1	0.27	**
Castle and Watson (1970)					
DMD(%)	62.9	65.5	2.6		
Intake silage (kg)	7.3	7.5	0.2	0.22	NS
conc. (kg)	5.0	5.0			
Milk Yield (kg)	16.0	16.7	0.7	0.22	NS
Castle and Watson (1971)					
DMD(%)	60.9	68.7	7.8		
Intake silage (kg)	7.6	7.9	0.3	0.22	*
conc. (kg)	5.1	5.1			
Milk yield (kg)	16.4	18.0	1.6	0.25	*
DMD(%)	62.2	71.9	9.7		
Intake silage (kg)	6.7	7.2	0.5	0.22	**
conc. (kg)	5.0	5.0			
Milk yield (kg)	16.3	17.6	1.3	0.22	*
Taylor and Aston (1976)					
DMD (%)	66.3	71.1	4.8		
Intake silage (kg)	6.5	5.6	-.9	0.32	*
dried grass(kg)	9.7	9.7			
Milk yield (kg)	19.5	19.3	-.2	0.51	NS
DMD (%)	64.7	70.7	6.0		
Intake silage (kg)	7.5	6.8	-.7	0.32	*

dried grass (kg)	6.4	6.4			
Milk yield (kg)	17.0	17.5	-.5	0.51	NS
Gordon and Murdoch (1978)					
DMD (%)	70.0	72.9	2.9		
Intake silage (kg)	9.8	11.9	2.1	0.33	**
conc. (kg)	3.8	3.8			
Milk yield (kg)	19.1	21.8	2.7	0.71	*
Castle *et al.* (1980)					
DMD (%)	62.4	65.0	2.6		
Intake silage (kg)	9.4	10.1	0.7		*
conc. (kg)	3.6	3.5			
Milk yield (kg)	16.8	17.0	0.2		NS
Gordon (1980a)					
DMD (%)	62.4	70.0	7.6		
Intake Silage (kg)	8.2	9.4	1.2	0.27	*
conc. (kg)	8.8	8.8			
Milk yield (kg)	21.0	23.9	2.9	0.27	*
Gordon (1980b)					
DMD (%)	61.7	72.6	10.9		
Intake silage (kg)	8.1	10.7	2.6		
conc. (kg)	7.6	7.6			
Milk Yield (kg)	23.3	26.1	2.8		**
Moisey and Leaver (1984)					
DMD (%)	61.5	66.4	4.9		
Intake silage (kg)	10.3	11.5	1.2	0.39	*
conc. (kg)	4.4	4.4			
Milk yield (kg)	18.3	20.1	1.8	0.85	*
Rogers and Robinson (1984)					
DMD (%)	71.6	73.5	1.9		
Intake silage (kg)	10.7	11.4	0.7	0.79	*
pasture (kg)	3.5	3.8			
Milk yield (kg)	11.5	12.3	0.8	0.79	*
DMD (%)	66.1	69.2	3.1		
Intake silage (kg)	10.6	11.3	0.7	0.79	*
pasture (kg)	3.5	3.8			
Milk yield (kg)	9.9	11.4	1.5	0.79	*
Phipps *et al.* (1987)					
DMD (%)	60.0	68.0	8.0		
Intake Silage (kg)	6.2	7.5	1.3	0.3	*
conc. (kg)	4.3	4.3			
Milk yield (kg)	13.4	15.3	1.9	0.81	NS

SEM : standard error of the mean
* : significance at P<0.05
** : significance at P<0.01
*** : significance at P<0.0001

The data from the published experiments show that the average response in term of milk yield was 0.23 kg milk per unit rise in silage digestibility. The data indicate the range in response from 0.00 (Taylor and Aston, 1976) to 0.93 (Gordon and Murdoch, 1978) kg milk per unit rise in silage digestibility. However most of the data shown in Table 5.2 relate to experiments in which silage was given in combination with concentrates thus, the effects of forage digestibility would be probably smaller than when forage is given as a sole feed (Thomas, 1980). When hay of different digestibilities were fed to the cows, Kaiser *et al.* (1987) and Llamas-lamas *et al.* (1987) found that cows fed on high digestibility hay required less concentrate in order to produce the same amount of milk compared to cows fed on low digestibility hay. The value of 0.23 kg milk per unit rise in digestibility observed in the present study was generally similar to those reported when silage of different digestibilities were fed.

Digestibility of the supplement is unlikely to affect milk yield directly. For instance, in the present study, if the cows in both low and high digestibility hay groups consumed the same amount of different digestibilities hay of 7 kgDM, the difference in ME intake per cow per day would be about 3 MJME. However, the cows consumed the greater amount of high digestibility hay i.e, the cows ate 8.7 kgDM and 6.5 kgDM of high and low digestibility hay respectively. This led to about 20 MJME difference in ME intake per cow per day in the two treatment groups. Therefore, the differences in herbage intake and total DM intake caused by different digestibilities of supplements seems to be the major factors responsible for the difference in milk production observed in the published experiments (Astibia *et al.* 1987; Llamas-lamas *et al.* 1987) as well as the present experiment. Since the high digestibility hay contains more soluble DM and has a faster rate of digestion, then a faster passage of the high digestibility hay, these would lead to a higher intake and better utilisation of DM and fibre (Castle, 1975; Llamas-lamas *et al.* 1987). Therefore, the DM digestibility of hay was correlated positively with the DM consumption (Astibia *et al.* 1987) and animal performance (Worrell *et al.* 1987). It was found that faecal loss per 100 units of gross energy intake decreases with increasing digestibility of the diets, the heat loss as a proportion of gross energy remained relatively constant but was therefore, markedly higher in proportion to the digested energy consumed from the lower digestibility diet (Armstrong, 1964). This indicates the low efficiency with which energy from low digestibility diets is utilised i.e, K values would be increase with increasing digestibility of the diets.

When silage of different digestibilities is fed to the cows as the basal feed and supplemented with concentrate, milk yield generally increases with increases in the digestibility value of silage (Castle, 1975). Once again, the increase in milk yield with the high digestibility value silage is due primarily to a higher intake of digestible organic matter from the higher quality silage (Castle and Watson, 1969, 1970, 1971; Castle, 1975; Rogers and Robinson, 1984; Moisey and Leaver, 1984; Phipps *et al.* 1987).

Many experiments found that when silage is fed as a basal feed, milk production generally increases with the increasing level of concentrate supplementation (Taylor and Aston, 1978; Gordon and Murdoch, 1978; Gordon, 1980ab; Castle *et al.* 1980) regardless of silage digestibility. Increasing the level of concentrate supplementation causes increases in the quantities of nutrients consumed and better utilisation of those nutrients, because the increase in digestible crude protein intake when cows are fed on low protein roughage would cause an increase in ration digestibility (Gordon and McMurray, 1978; Gordon, 1980a). The higher milk production by the cows fed on the high digestibility hay observed in the present study may be due partly to the very low concentration of crude protein in the low digestibility hay (6.85%) compared to the high digestibility hay (17.70%) (Table 4.4). The quantities of total digestible crude protein eaten by cows fed on low and high digestibility hay were 84 and 130 gm per cow per day respectively. The total digestible crude protein eaten by cows fed on low digestibility hay was lower than the cows' requirements, recommended by ARC (1980), at the level of production obtained (14.7 and 16.0 kg milk per cow per day in low and high digestibility hay group respectively) whereas digestible crude protein consumed in high digestibility hay was matched to cows' requirements. Since Friesian cows weighing about 350 - 450 kg produce 15 kgFCM per day and any liveweight change requires about 131 gm digestible crude protein per day (Holmes and Wilson, 1984). It is possible, therefore, that high digestibility hay can be utilised with better efficiency, partly because of the better nutritional balance. These would lead to the conclusion that the higher milk yield observed in the high digestibility hay group may be attributed to the higher nutrients consumed and utilised when high digestibility hay was fed to the cows.

5.2.2 Yield of milk constituents.

In addition to the higher milk yield, yields of milk fat, milk protein and milk lactose were slightly higher, but not significantly, in cows fed high digestibility hay (Tables 4.7abcd). The increased yield of these components was due to the increase in milk yield in the cows fed the high digestibility hay, and occurred despite slight decreases in the concentration of milk fat and milk protein. Yields of milk fat, however, decreased significantly ($P<0.05$) with the progress of time during the experiment. This may due to the exhaustion of body reserves mobilised during a prolonged period of relative underfeeding.

5.2.3 Residual effects on yield of milk and its constituents.

In the present study, the small difference in milk yield between treatment groups virtually disappeared within one week after the termination of the period of differential feeding experiment (Tables 4.7abcd, Tables 4.8abc).

The absence of a residual effects in this study would be expected since the difference in yields between the two treatment groups were small at the end of the experiment. Also it was probably because the cows were well fed both before and after the experiment. Therefore, they were in reasonably good condition score (4.3 and 3.8 in low and high digestibility hay groups respectively) at calving to cope with the short period of underfeeding without jeopardizing subsequent production. In addition, cows which are well fed can recover immediately after the termination of a short period of underfeeding with no residual effect (Grainger *et al.* 1982). In the present experiment the recovery period was less than 6 days since production was sampled every 6 day interval. In conclusion, if the supply of herbage is abundant following the period of mild underfeeding, there will be no carry over effect on yield of milk and its constituents, provided that cows calved in good condition (Stakelum, 1986ab).

5.2.4 Composition of milk.

The digestibility of hay had no significant effect on concentration of milk fat, milk protein and milk lactose throughout the experiment in the present study. Although milk fat concentration for the low digestibility hay group was significantly ($P<0.05$) higher in the first week of the experiment, the differences between two treatment groups decreased as the experiment advanced (Table 4.8a). Milk protein concentration was also slightly higher, but not significantly, throughout the experiment for cows fed on low digestibility hay (Table 4.8b).

When silage of different digestibilities was fed as a basal feed and supplemented with concentrate, the effects on concentrations of milk fat and milk protein were varied and not consistent (Table 5.3). This depends largely on the level of concentrate feeding (Castle *et al.* 1980).

Table 5.3 Effects of the digestibility of conserved forage on the concentration of milk constituents, from published data and the present experiment.

Detail	Digestibility of forage		Diff bet.		level of
	Low	High	trt.	SEM	significance
HAY					
The present experiment					
DMD (%)	52.0	57.3	5.4		
Intake hay (kg)	6.5	8.7	2.2	0.29	***
pasture (kg)	4.3	3.9			
Fat (%) 4.67	4.40	0.27	0.19	NS	
Protein (%)	3.25	3.14	0.11	0.09	NS
Lactose (%)	5.08	5.02	0.06	0.06	NS
SILAGE					
Castle and Watson (1969)					
DMD (%)	67.0	74.0	7.0		
Intake silage(kg)	6.1	6.9	0.8	0.28	*
conc. (kg)	5.2	5.2			
Fat (%) 4.16	4.11	0.05	0.10	NS	
Protein (%)	2.81	2.81	0.00	0.03	NS
Lactose (%)	4.52	4.54	0.02	0.08	NS
Castle and Watson (1970)					
DMD(%)	62.9	65.5	2.6		
Intake silage (kg)	7.3	7.5	0.2	0.22	NS
conc. (kg)	5.0	5.0			
Fat (%) 4.56	4.48	0.08	0.08	NS	
Protein (%)	3.06	3.07	0.01	0.03	NS
Lactose (%)	4.82	4.83	0.01	0.02	NS
Castle and Watson (1971)					
DMD(%)	60.9	68.7	7.8		
Intake silage (kg)	7.6	7.9	0.3	0.22	*
conc. (kg)	5.1	5.1			
Fat (%) 4.48	4.15	0.33	0.07	NS	
Protein (%)	3.25	3.33	0.08	0.03	NS
Lactose (%)	4.80	4.80	0.00	0.03	NS

DMD(%)	62.2	71.9	9.7		
Intake silage (kg)	6.7	7.2	0.5	0.22	**
conc. (kg)	5.0	5.0			
Fat (%) 4.48	4.27	0.21	0.07	NS	
Protein (%)	3.20	3.23	0.03	0.03	NS
Lactose (%)	4.81	4.80	0.01	0.03	NS
Taylor and Aston (1976)					
(Early lactation.)					
DMD (%)	66.3	71.1	4.8		
Intake silage (kg)	6.5	5.6	-.9	0.32	*
dried grass (kg)	9.7	9.7			
Fat (%)	3.33	3.30	0.03	0.08	NS
Protein (%)	3.05	3.07	0.02	0.07	NS
Lactose (%)	4.93	4.92	0.01	0.06	NS
(Mid Lactation.)					
DMD (%)	66.3	61.1	4.8		
Intake silage (kg)	8.5	7.7	-.8	0.27	NS
dried grass (kg)	6.0	6.0			
Fat (%)	3.27	3.36	0.09	0.08	NS
Protein (%)	2.91	2.92	0.01	0.08	NS
Lactose (%)	4.90	4.86	0.04	0.06	NS
Castle *et al.* (1980)					
DMD (%)	62.4	65.0	2.6		
Intake silage (kg)	9.4	10.1	0.7		*
conc. (kg)	3.6	3.5			
Fat (%) 4.10	3.80	0.30		NS	
Protein (%)	3.10	3.09	0.01		NS
Lactose (%)	4.67	4.65	0.02		NS
Gordon (1980a)					
DMD (%)	62.4	70.0	7.6		
Intake silage (kg)	8.2	9.4	1.2	0.27	*
conc. (kg)	8.8	8.8			
Fat (%) 4.22	4.00	0.22	0.07	**	
Protein (%)	3.37	3.46	0.09	0.06	NS
Lactose (%)	4.60	4.57	0.03	0.03	NS
Gordon (1980b)					
DMD (%)	61.7	72.6	10.9		
Intake silage (kg)	8.1	10.7	2.6		
conc. (kg)	7.6	7.6			
Fat (%) 3.68	3.77	0.09	0.09	NS	
Protein (%)	3.07	3.25	0.18	0.06	NS
Lactose (%)	4.69	4.78	0.09	0.03	NS
Moisey and Leaver (1984)					
DMD (%)	61.5	66.4	4.9		
Intake silage (kg)	10.3	11.5	1.2	0.39	*
conc. (kg)	4.4	4.4			
Fat (%) 4.06	3.88	0.18	1.00	NS	
Protein (%)	3.11	3.33	0.22	0.48	*

Lactose (%)	4.67	4.82	0.15	0.34	*
Phipps *et al.* (1987)					
DMD (%)	60.0	68.0	8.0		
Intake silage (kg)	6.2	7.5	1.3	0.3	*
conc. (kg)	4.3	4.3			
Fat (%) 4.01	3.97	0.04	0.14	NS	
Protein (%)	3.04	3.18	0.14	0.08	*
Lactose (%)	4.62	4.65	0.03	0.06	NS

SEM : standard error of the mean
* : significance at P<0.05
** : significance at P<0.01
*** : significance at P<0.0001

In the present study, concentration of milk fat and milk protein were slightly higher in cows fed on low digestibility rather than high digestibility hay. This may have been due to the fact that cows fed on low digestibility hay were more severely underfed, and they were in higher body condition at the start of the experiment. Therefore they may have mobilised their body reserves more heavily than cows fed on high digestibility hay. This would have resulted in a higher concentration of milk fat and milk protein (Rogers *et al.* 1979; Grainger *et al.* 1982; Holmes and Wilson, 1984) in cows given low digestibility hay. However, in this case, the effect on concentration of milk fat would have been expected to be larger than the effects on milk yield and milk protein. In addition the differences in milk fat and milk protein between the two treatment groups declined gradually with progress of time during the experiment. This may have been due to the exhaustion of body reserves and/or the increased in pasture intake by cows fed on low digestibility hay with the progress of the experiment. The concentration of milk lactose in the present study was not affected by hay digestibility which is similar to most data presented in Table 5.3.

Effects on the composition of milk were small when cows were fed on silage of different digestibilities and supplemented with concentrate (Castle and Watson, 1969, 1970, 1971). However increases in the concentration of milk protein (Moisey and Leaver, 1984; Phipps *et al.* 1987) and milk lactose Moisey and Leaver, 1984) with increasing digestibility of silage were observed, whereas Gordon (1980a) observed an increase in milk fat concentration with increasing silage digestibility. The variability of these data may be due to the differences in the degree of underfeeding, cow quality, cows' condition and level of concentrate feeding in each individual experiment. Moisey and Leaver (1984) and Gordon (1980a) suggested that the higher concentration of milk fat when low digestibility silage was fed, was due to the high fibre of the ration and consequently change in rumen fermentation. However Castle and Watson (1970, 1971) stated that the amount of fibre contained in both low and high digestibility hay was sufficient to maintain milk fat concentration. The higher protein concentration observed by Moisey and Leaver (1984) and Phipps *et al.* (1987) and higher lactose concentration observed by Moisey and Leaver (1984) may have been due to the higher ruminal proprionic acid production due to the higher energy status of the cows fed on high digestibility silages (Phipps *et al.* 1987; Castle and Watson, 1969). An increase in supply of proprionic acid has been shown to stimulate the synthesis of milk protein (Rook and Balch, 1961).

5.3 Effects of hay digestibility on changes in liveweight and condition score.

Generally, there is a decrease in liveweight in the first few weeks after calving followed by the period of gain (Broster and Thomas, 1981; Bryant and Trigg, 1982). An increase in silage digestibility results in a reduced rate of mobilisation of body reserves consequently, in a reduced rate of liveweight loss. Therefore increase digestibility of supplement can causes increases in condition score measured at the end of the experiment.

In the present study, faster liveweight gain was shown by the cows fed on high digestibility hay compare to low digestibility hay (Table 4.9). The significant difference ($P<0.05$) in initial condition score was not expected since cows were randomly allocated to each group. The final score in the present study was not significantly different between groups, but there was a significant difference in the change in the condition score ($P<0.01$), because cows fed on high digestibility hay gained more condition than those on low digestibility hay (Table 4.9).

Most of the data in Table 5.4 show similar results, indicating that liveweight gains of cows fed on high digestibility conserved forage is significantly greater than the mean liveweight gains of cows fed on low digestibility conserved forage.

Table 5.4 Effects of the digestibility of conserved forage on liveweight and condition score changes, from published and the present experiments.

Detail	Digestibility of forage Low	High	Diff bet. trt.	SEM	level of significance
HAY					
The present experiment					
DMD (%)	52.0	57.3	5.4		
Intake hay (kg)	6.5	8.7	2.2	0.29	***
pasture (kg)	4.3	3.9			
LW change (kg/day)	+0.30	+0.62	0.32	0.12	*
CS change	+0.21	+0.44	0.23	0.10	**
SILAGE					
Castle and Watson (1969)					
DMD (%)	67.0	74.0	7.0		
Intake silage(kg)	6.1	6.9	0.8	0.28	*
conc. (kg)	5.2	5.2			
Lw change (Kd/day)	-0.97	-0.73	0.34	0.31	**
Taylor and Aston (1976)					
(Early lactation.)					
DMD (%)	66.3	71.1	4.8		
Intake silage (kg)	6.5	5.6	-.9	0.32	*
dried grass (kg)	9.7	9.7			
LW change (kg/day)	-0.26	-0.04	0.22	0.10	**
(Mid Lactation.)					
DMD (%)	66.3	61.1	4.8		
Intake silage (kg)	8.5	7.7	-.8	0.27	NS
dried grass (kg)	6.0	6.0			
LW change (kg/day)	-0.40	-0.04	-0.36	0.10	**
Gordon and Murdoch (1978)					
DMD (%)	70.0	72.9	2.9		
Intake silage (kg)	9.8	11.9	2.1	0.33	**
conc. (kg)	3.8	3.8			
LW change (kg/day)	-0.19	-0.21	0.02	1.00	NS
Castle *et al.* (1980)					
DMD (%)	62.4	65.0	2.6		
Intake silage (kg)	9.4	10.1	0.7		*
conc. (kg)	3.6	3.5			
LW change (kg/day)	-0.20	-0.03	0.17		*
Gordon (1980b)					
DMD (%)	61.7	72.6	10.9		
Intake silage (kg)	8.1	10.7	2.6		
conc. (kg)	7.6	7.6			
LW change (kg/day)	-0.24	-0.10	0.14		*
CS change	-1.0	-1.3	0.3	0.34	*

Moisey and Leaver (1984)					
DMD (%)	61.5	66.4	4.9		
Intake silage (kg)	10.3	11.5	1.2	0.39	*
conc. (kg)	4.4	4.4			
LW change (kg/day)	-0.12	+0.24	0.36	0.08	*
CS change	-o.27	+0.10	0.37	0.10	*
Rogers and Robinson (1984)					
DMD (%)	71.6	73.5	1.9		
Intake silage (kg)	10.7	11.4	0.7	0.79	*
pasture (kg)	3.5	3.8			
LW change (kg/day)	+0.90	+1.20'	0.30	0.47	*
DMD (%)	66.1	69.2	3.1		
Intake silage (kg)	10.6	11.3	0.7	0.79	*
pasture (kg)	3.5	3.8			
LW change (kg/day)	+0.65	+1.40	0.75	0.47	*
Phipps *et al.* (1987)					
DMD (%)	60.0	68.0	8.0		
Intake silage (kg)	6.2	7.5	1.3	0.3	*
conc. (kg)	4.3	4.3			
LW change (kg/day)	0.37	0.36	0.01	0.08	NS

SEM : standard error of the mean
* : significance at P<0.05
** : significance at P<0.01
*** : significance at P<0.0001

The significantly (P<0.05) higher liveweight gains obtained in cows fed on high digestibility hay, reflect the greater energy intake and the partition of some of the addition of ME to body weight gain. In addition, a higher proportion of proprionic acid produced in the rumen of cows fed on high digestibility diets may stimulate body tissue synthesis (ARC, 1980; Rook and Thomas, 1983). The increased liveweight gain of 324 gm per day in cows fed on high digestibility hay during the experimental period might be utilised to produce milk in the subsequent period of lactation or in the next lactation (Holmes and MacMillan, 1982; Wilson and Davey, 1982). However, the data recorded in the present study did not allow the utilisation of body reserves in the subsequent period to be measured. The benefit of increase in liveweight and condition score could be carried to the next lactation as cows calving in better condition should produce more milk in lactation (Grainger *et al.* 1982)

5.4 Calculated energy balance.

Eldrige and Kat (1980a) suggested that digestibility of pasture consumed was not affected by hay supplementation. Therefore, the energy balances of cows in both treatment groups can be calculated as shown in Table 5.5.

Table 5.5 Calculated energy balance for the two treatments.

	Low digestiblity hay	High digestibility hay
Total DM intake (kg/day)	10.85	12.50
Estimated ME intake (MJ/day)	99	115
From pasture	48	43
From hay	51	72
Gain in body energy[a] (MJ/day)	11	24
ME for maintenance[b] (MJ/day)	54	55
ME available for milk (MJ/day)	34	36
Expected milk energy[c] (MJ/day)	22	23
Actual milk energy[d] (MJ/day)	70	77

a : using 35.8 MJ/kg liveweight gain (Holmes and Wilson, 1984)
b : Using $k_m = 0.60$ MJ/kg$^{0.75}$ (Holmes *et al.* 1981)
c : Assuming $k_l = 0.65$ (Holmes and Wilson, 1984)
d : calculated from actual FCM milk yield and estimated that one kgFCM = 4.8 MJ (Holmes and Wilson, 1984).

Cows fed on high digestibility hay produced more milk and gained more weight than cows fed on low digestibility hay, due probably to the increase in ME intake by cows fed on the high digestibility hay.

The differences between the two groups in ME intake and in liveweight gain and milk yield, do agree in energetic terms. For instance, actual differences in liveweight gain and milk yield were: 0.32 kg per day which is equal 13 MJME per day together with 1.3 litre of milk per day which represent about 6 MJME intake. The calculation is similar to 16 MJ per day differences in ME intake between the two treatment group.

Considering that cows fed on high digestibility hay gained more liveweight than cows fed on low digestibility hay, by theoretical calculation and as shown in Table 5.5, the higher actual milk energy than expected milk energy may arise from many factors, including an underestimated of ME intake, and over estimate of liveweight gain.

An under estimate of pasture DM intake is likely to occur since the accuracy of cutting the grass during the experiment was difficult because of heavy rain and muddy swards. However, the total DM intake of cows in this experiment showed that feed intake measurements were reasonably consistent. It was possible that gut fill may contribute to an overestimate of liveweight gain since cows were weighted on day 2 after the termination of the experiment and all the hay may not completely removed from the gut.

CHAPTER 6

CONCLUSIONS

Milk yield was increased slightly by the feeding of high digestibility hay. The value of 0.23 Kg milk per unit difference in percentage digestibility of hay was observed in the present study. Yield of milk fat, milk protein and milk lactose were also increased slightly because of the increase in milk volume, and despite no changes in milk composition.

Cows fed on high digestibility hay gained significantly more liveweight and condition score than cows fed on low digestibility hay.

Total intake of dry matter and metabolisable energy were increased significantly in cows fed on high digestibility hay. This increase occurred because hay intake increased by 0.40 KgDM per unit difference in percentage digestibility of the hay and, despite the fact that herbage intake was decrease in the cows which ate the high digestibility hay. This treatment group also left greater residual herbage masses after grazing.

Results in the present study show the benefits of feeding high digestibility hay. There were immediate effects (increased yields of milk and milk constituents) and a longer term benefits since the cows fed high quality hay finished the experiment with higher liveweight and condition score, and pasture was spared for use at a later periods. In addition, spared pasture may increase pasture growth rates in subsequent periods through the increase in leaf area index.

However the earlier cutting and an increased frequency of cutting required to produce high digestibility herbage for conservation, may result in a reduction in yield of grass DM and often digestible OM. The need, therefore, to integrate milk yield responses with agronomic information has been recognised in order to maximise milk yield and profit per farm. Thomas (1980) suggested that the use of cutting systems to produce conserved pasture of relatively low digestibility results in highest digestible nutrient yield per hectare which enables stocking rate and consequently milk yield per hectare to be increased. The optimum cutting time and frequency of cutting depend largely on type of animal and husbandry strategies (Blaxter and Wilson, 1963). In addition, Stockdale and King (1982) suggested that cows can not eat enough hay to overcome underfeeding in early lactation but the residual benefit of feeding hay beyond the period of supplementation is a key factor to determining the total benefits of hay feeding in early lactation. They also suggested that supplementation of hay is not recommended for dairy cows in early lactation because it is unlikely to be economic. The conclusion in the present study is, however, that high digestibility hay supplementation would be more beneficial than low digestibility hay supplementation when the supply of pasture is limited, particularly on those farms with an earlier calving date. This is because the higher feeding value of high digestibility hay make it more suitable than low digestibility hay for supplementation to dairy cows in early lactation. The long term effect of high digestibility hay supplementation seems to be even more important since the greater liveweight and the extra body condition gained during the period of supplementation could subsequently be mobilised for milk synthesis in the later stages.

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